Finding Optimal Locations for Electric Vehicle Charging Stations Based on Genetic Algorithm

by

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Abstract

In this day and age, environment is the main concern. And to achieve a sustainable future regarding technology, electric vehicle can be a major gateway to reduce carbon emission. In Bangladesh, electric vehicle is not prominent when it comes to transportation. There are a lot of reasons behind this. But the most important one that needs to be solves is the lack of efficient charging stations infrastructure. A charging station infrastructure provides a quintessential service which is charging in between destinations. And for that purpose, they have to be located in such a way so that, the EVs can be charged in an efficient manner. This is where the necessity of optimal locations arises.

The objective of this research is pretty simple. This research offers the best locations among other important location where a charging station should be built. Recent statistics shows us that Dhaka, the capital of Bangladesh, has become the most polluted city in the world. And it is very important to reduce carbon emission in this city where EVs can be of great help. In order to solve this problem, this research takes Banani, an important part of Dhaka city as a location in order to completer the thesis. Depending on the [1] relevant information provided, this paper first tries to build a model which calculates the distance cost .Based on that, an objective function is formulated which takes distance cost minimization as its primary concern. An optimization [36] algorithm is used to find the best and optimum locations. The algorithm is genetic algorithm which finds the fittest solution according to the objective function and the constraints provided. This solution solves the distance cost minimization problem under the constraints of the capacity of the charging stations and the location from where the EV flow will start.

Finally, after finding the results, we have crosschecked them by changing the number of vehicles, the capacity [27] of the locations and the number of charging stations itself to have a good idea on how this research actually served its purpose.

Chapter 1

Introduction

In recent years, the electric vehicle (EV) has been seen as an effective way to reduce the current resource problem, energy problem, and environmental problems due to its high performance, energy saving, low noise, and zero emissions. EVs have been widely promoted and used worldwide since the beginning of environmental concerns. Many countries are developing EVs through incentive policies. Bangladesh is a densely populated country, but the use of major resources and energy problems has been a barrier to Bangladesh's rapid and healthy development. And EVs can be a deep solution and can be a milestone in the development of this country in the future. However, the lack of charging stations has become a barrier to the development of new EVs. EVs rely on charging points as the fuel truck relies on petrol stations. By adjusting the charging station distribution we can proficiently meet the changing necessities of electric vehicles. Therefore, it has become an important research topic to find the appropriate distribution of EV charging stations.
There are a number of scholars who have done extensive research on this subject with differing opinions. This study focuses on reducing the cost of distance.

While distributing the charging stations the number and location has become an important factor affecting the development of the electric car industry. There are different economic and social factors that are related to it. In conclusion, the analysis and research of numerical adjustments and local distribution of charging stations is critical to the popularity of electric vehicles. Therefore, this study selects Banani, an important part of the capital as a research subject.

1.1 Problem Definition

To create a proficient charging station infrastructure for EVs, finding optimal locations for establishing these charging stations is primary priority. In this research, we are addressing this prime concern of finding the locations. This research is limited to minimizing total distance cost as the primary parameter and taking capacity a constraints.

1.2 Aims and objectives

1.2.1 Aims

The aim of this research is to take the initial step of creating the m milestone for an efficient charging station infrastructure by finding the optimal location for the upcoming charging stations. Doing so, it will help persuade the customers to use EVs as their primary transportation option, because there is already a system for them to provide.

1.2.2 Objectives

Our objective is to find the optimal locations for charging stations in Banani so that,

- Vehicles can find the optimal location to get charged.
- Cost per kilometer would be optimal by the locations.

1.3 Background and Motivation

The motivation behind this is pretty simple but intriguing. We are doing this research based on the city of Dhaka (specifically Banani), that became the most polluted city in the world. And one of the reasons is the fuel based vehicles. EVs will be a good replacement because it will provide a better outcome for both environment and economy. Because,

1. Less pollution, renewable energy,
2. Better for health,
3. Cheaper to run, cheaper to maintain,
4. Better for our energy security

Even though there are so many benefits, it is hard to convince people about using EVs, because we don't have proper infrastructure for charging stations. To persuade the customers and make the whole system efficient, making charging stations at optimal locations is top priority. That is what we are trying to achieve through this research, finding optimum locations for EV charging stations

Currently EVs are not used in Bangladesh on a large scale. But a hybrid car is available on a smaller scale. It shows that people love EVs but it has been difficult for them to change due to lack of infrastructure.

If we do an overview of the 4 wheel hybrid car market, we will see the demand for integrated vehicles has increased over the past few years. In terms of sales, this figure has been steadily rising until the epidemic by 2020. In 2018, the four-wheeled hybrid market registered a 900% increase in sales.

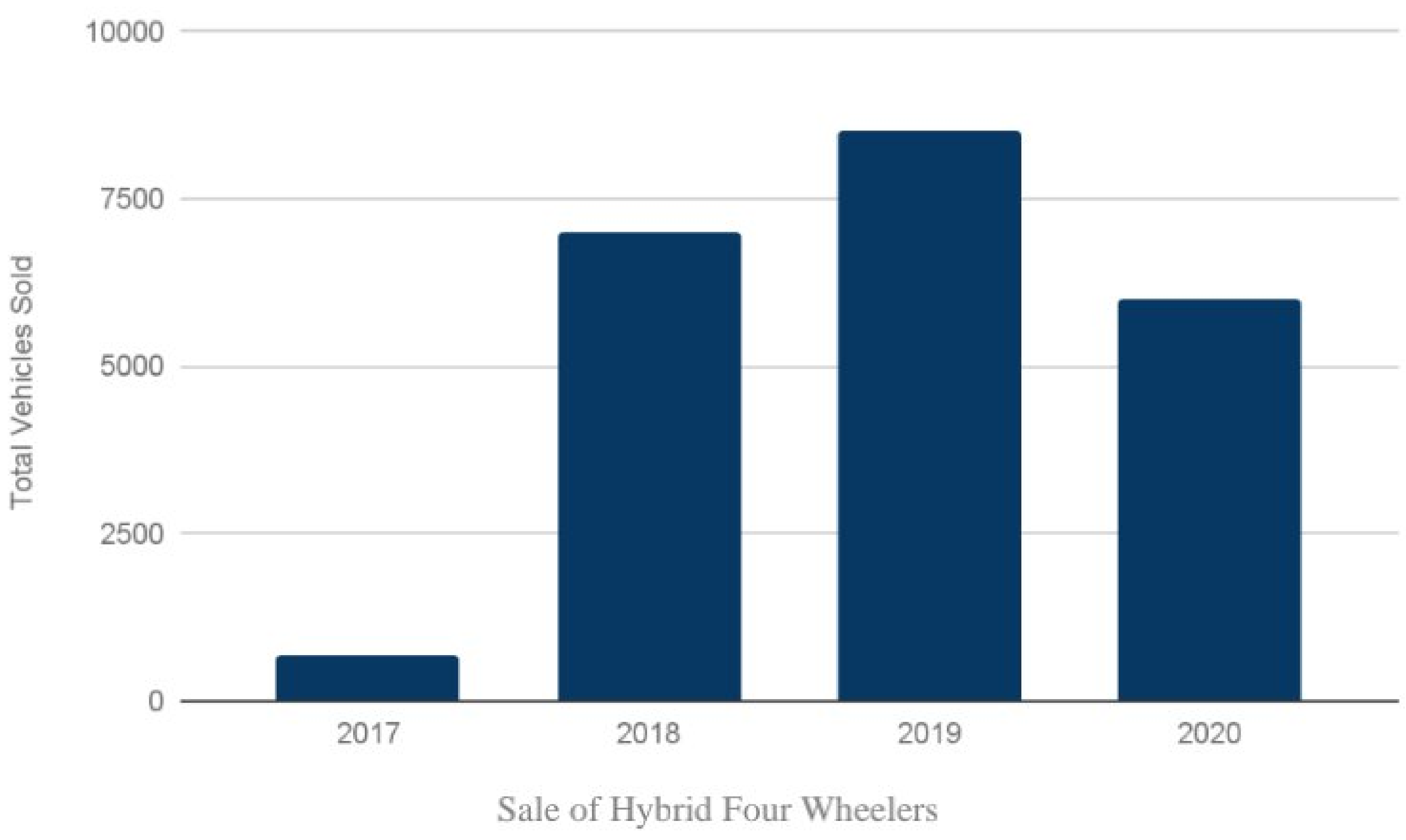

Figure 1.1: Sale of Hybrid Four-Wheelers in Bangladesh / Source: LightCastle Primary Interviews

According to one of Bangladesh's leading car dealers / distributors, one of Bangladesh's leading car dealerships, a typical 1600cc petrol car can run 7-8 km / liter, and a hybrid car with the same specifications can drive up to 15 -16. km for the same amount of fuel.

The four-wheeled EV market is more or less non-existent in Bangladesh. Currently, it is estimated that there are less than 10 EV passengers in the country, all of them in Dhaka. However, the market is likely to improve in the future as the country expects to receive significant investment in the sector. In addition, Bangladesh Auto Industries Ltd. (BDAuto) has invested $ 200 million in the country to make electric SUVs, sedans, hatchbacks, two-wheel drive, and three-wheel drive.

Now that we look at the tax situation, the car market in Bangladesh is heavily organized by the government with this one key tool. Vehicle label prices usually mean nothing to Bangladeshi buyers, as the unusually high import duty on cars in Bangladesh is about 827%. The tax incidence depends equally on the volume of the cylinder (CC) of the vehicle. If we look at the table below, we will see that the tax rate is ridiculously low when it comes to electric cars and hybrid cars.

Cylinder Capacity (CC)	Total Tax Incidence		
	CBU Gasoline	CKD Gasoline	Hybrid CBU
<= 1600	128%	89%	N/A
<= 1800	N/A	N/A	89%
1601 - 2000	212%	128%	N/A
1801 - 2000	N/A	N/A	127%
2001 - 3000	366%	212%	150%
3001 - 4000	596%	519%	212%
>4000	827%	742%	520%
CBU Electric	59%		

Table 1.1: Tax Incidence on Automobiles in Bangladesh / Source: PRI, Primary Interviews

.

These information got us thinking if EVs are better than fuel-based vehicle, why aren't there any reasonable amount of users in Bangladesh? The next table answers this question

Country	Total EV Charging Stations	Road Distance between Every Charging Stations(km)
Bangladesh	14	26365
United States	41400	159
United Kingdoms	35000	11
Japan	18000	68
India	933	5036

Table 1.2: EV Charging Infrastructure Comparison / Source (Road Network): CIA

As we can see from this table, Bangladesh is lacking a proper charging station infrastructure even though a reasonable amount of people is eager to use EVs. If a customer has to drive this much to find charging stations, it will not be possible for this country to create a suitable scenario for electric vehicles.

This is why we took on this research, to provide a solution for this problem.

Chapter 2

Literature review

The research on the location of electric vehicle charging stations can be divided into the following three categories: one is to study factors influencing the location of the charging station, the other is to build a model for optimal location, and the third is the algorithm associated with the model.

In [1], two-stage optimization frameworks for the planning of electric vehicles charging stations powered by batteries have been developed. In two stages, genetic algorithm and linear programming were used o find out the optimal results. Here, the travelling cost to the charging station, along with the station building cost are determined. In [2], a mathematical model is written to find out the optimal positions for electric vehicle charging stations and genetic algorithm is used to solve the model. A method of finding the best positions and determining the building cost of charging station for electric vehicle based on grid partition is proposed in [3]. This method is aimed at determining the best route to the charging station from some particular locations and finding the lowest cost for travelling and choosing the best location of each partition in GA (Genetic Algorithm). A new optimal EV route model is proposed in [4] considering the different types of charging methods and the time that the charging stations are used. The proposed model aims to is used to determine the number of vehicles suitable for the charging station, the optimal position of the charging station for electric vehicles, the total building cost for the station and solved using learnable partheno-genetic algorithm. In [5], the model is built upon the concept of regional traffic density, where the traffic condition of a certain area is taken into consideration. On this basis, the minimum cost to travel from particular area to the station is found out and then, the genetic algorithm is applied to find the solutions. A novel methodology to perform optimization of electric vehicle charging station locations is presented in [6]. The problem is constructed in a way that it represents a grid of a particular area and in that area and the grids are used to find out the optimal location for electric vehicle charging station. In [7], an optimized algorithm is proposed to locate electric-vehicles charging stations. A mathematical model is created based on the travelling distance, travelling cost, duration of use of electric vehicle charging station and the number of electric vehicles situated in the station and solved using genetic algorithm. An Improved Whale Optimization Algorithm (IWOA) is proposed in [8] where a model is formulated based on the service risk constraints and applied IWOA to solve it. In this paper, the customer satisfaction and service feasibility are taken into consideration to find out the optimal location for charging stations.

Chapter 3

Methodology

3.1 Model construction and solution

For calculating the total cost accurately, we have created a total cost model based on distance cost. We defined the location from two perspectives. One is the locations of the charging stations and others are the locations of where the EV flow will start. The process of building this model is divided into two parts: the first part is to build the total distance cost model. The second part is to optimize the model. And we have taken the capacity of these locations as our constraints.

In this research, we have taken a constant value of 5 locations from where the EV flow will start. These locations are divided into two parts regarding the capacity of them keeping multiple vehicles at once. We have also taken constant values for the capacity of these locations. The locations with the capacity of 6-10 vehicles are taken as small places. For example: houses, small garages etc. And the locations with capacity of 10-20 vehicles are considered as large places such as shopping malls, hospitals, schools etc.

According to the mathematical model with the association of all the information, we have yield the formula,

$$\sum_{i=3}^{7} \boldsymbol{x}(\boldsymbol{i}) * \mathbf{10}\sqrt{}[\{(\boldsymbol{x}(\mathbf{1}) - \mathbf{10}\boldsymbol{cx}(\boldsymbol{i}-\mathbf{2})\}^{\mathbf{2}} + \{\boldsymbol{x}(\mathbf{2}) - \mathbf{10}\boldsymbol{cy}(\boldsymbol{i}-\mathbf{2})\}^{\mathbf{2}}]$$

We are taking this formula as our primary objective functions. In this function, cx is x coordinate of the location, cy is y coordinate of the location..

Constraints:

The capacity of the charging stations and the locations where the EV flow will start are taken as our constraints.

Location 1 vehicle capacity $x(3) = 6<x(3)<10$

Location 2 vehicle capacity $x(4)= 10<x(4)<20$

Location 3 vehicle capacity $x(5)= 6<x(5)<10$

Location 4 vehicle capacity $x(6)= 6<x(6)<10$

Location 5 vehicle capacity $x(7)= 10<x(7)<20$

Charging Station capacity $x(3)+x(4)+x(5)+x(6)+x(7) = x(3)+x(4)+x(5)+x(6)+x(7)>20$

These constraints indicates that the number of vehicle in a small place should not exceed 10 and for large places, 20. And for the charging station capacity, the number of vehicles coming from the locations will not exceed 20 at the same time. From x(3) to x(7) indicate the capacity of the locations of the small and large places. And x(1) and x(2) will indicate the coordinates of the optimal locations where the charging station should be built

Based on these parameters, we have created a calculative model that can near accurately measure the total distance cost, and then we can evaluate the total distance cost required under different scenarios according to the changes of the parameters and minimize it.

3.2 Optimization by Genetic Algorithm

Genetic algorithm is a multi-objective optimization algorithm which is metaheuristic. It is primarily influenced and based on Charles Darwin's theory of evolution that is actually the process o natural selection.. The algorithm works in a similar way of the process according to Darwin's theory. Fitness is the priority of first order when it comes to this algorithm. According to Darwin's theory, among the chromosomes, it is naturally selected that the fittest one will be chosen for the production of next generation and through that the offspring created from this reproduction will be of maximum fitness. So, as we can see, this theory is based on the actual living organisms in nature. And as it is always searching for the result with the maximum fitness, this algorithm is typically used for maximizing any function. However this algorithm can also be used for minimization by creating the objective function in such way. Another way can be taking the constraints by keeping the minimization of the desired function in mind.

In the genetic algorithm, the result with the maximum fitness is achieved through coding and iterations. These iterations are called as generation just as it is in the theory. The algorithm keeps iterating until it finds the fittest function. What it actually does is it keeps generating solutions until it finds the local optima and using these local optima it finds the global optima which is the best result among the other ones that were found earlier. There is a term called crossover in the process of natural selection. It is very efficiently used in this algorithm. For example, if a society has a very strong family (from a biological point of view), it is pretty obvious that their children will be the strongest of the next generation the cross over happened between the parents. And strong parents will give birth to strong children according to the theory of natural selection. So, how the crossover is happening or the performance of crossover is very important as it shows the data exchange of DNA between father and mother.

The primary constituents of the algorithm are a product of five key elements which are

- initial configuration,
- parameter coding,
- fitness design,
- performance configuration and
- parameter setting

These parameters actually implicates the five stages of the natural process that are,

- Variation,
- Inheritance,
- Selection,
- Time and
- Adaptation

There are five parts, based on what the algorithm progresses. These are,

1. The first population
2. Strength work

3. Choice
4. Crossover
5. Flexibility

The main theme on what the algorithm works can be implemented in any sort of search query. Generally, some random results are taken, and then the algorithm helps us find out the best one out of them. The pattern of the algorithm is shown in Figure 1.2

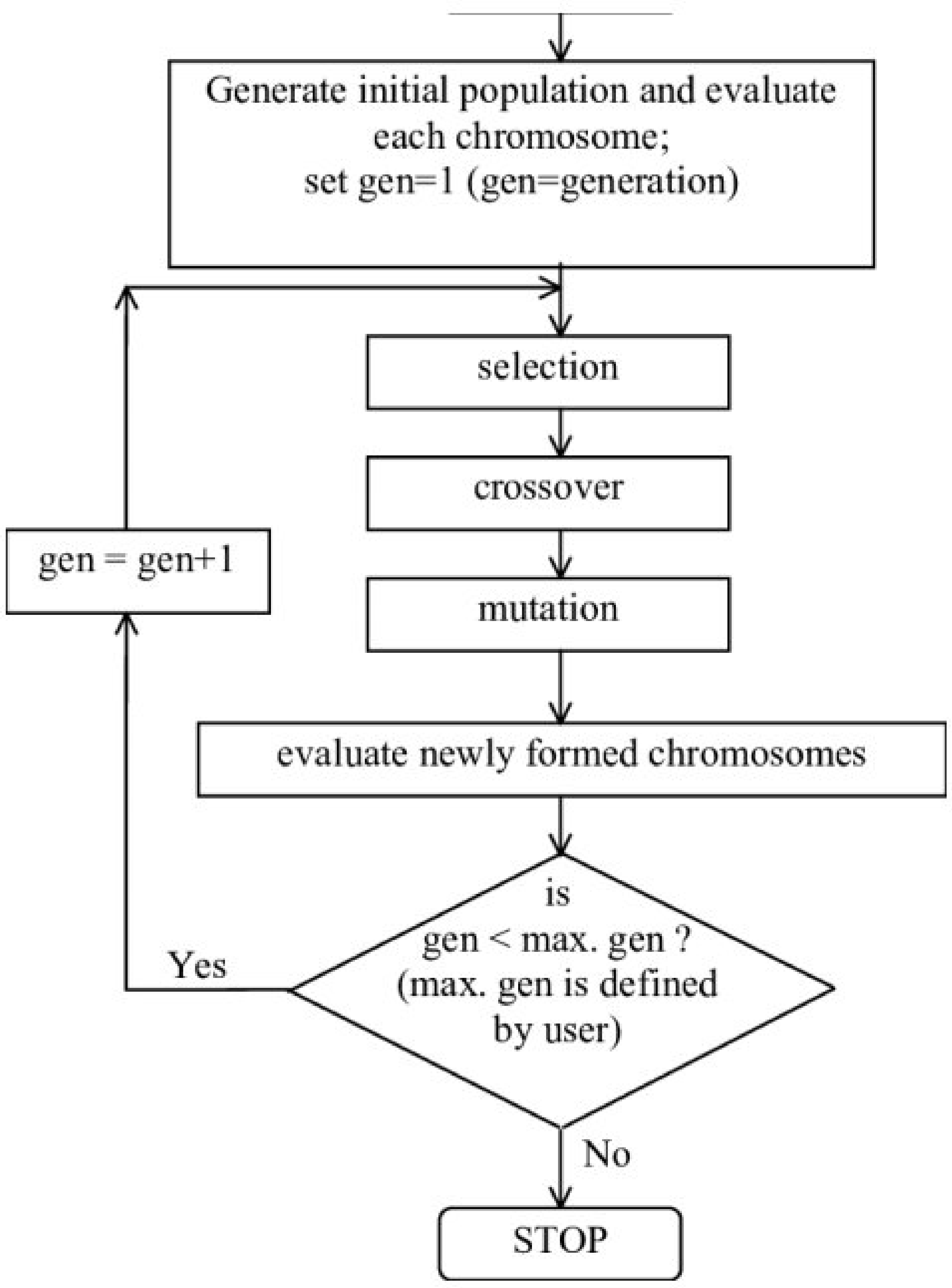

Figure 1.2: Process of GA

It is often seen that a genetic algorithm, like the performance algorithm, has the some understandable benefits compared to other algorithms: first, Genetic algorithm (GA) may be a global search method that mimics evolution. In line with the goal of the survival of the fittest and the survival of the fittest in biological evolution, the right amount of solution work is obtained by coding and continuous evolution. In the GA algorithm, selection, crossing and flexibility are three tasks. Crossover performance is that the main method of the genetic algorithm for providing for offspring, as well as the exchange of information between individual parents occurs through crossover, which is more than that which is typical for many generations of young people.

String is a set of something that can be represented as a whole. In GA, it holds a very important place. In this algorithm, string is utilized to represent a set or a packet of genes by using alphabet for easier comprehension. However, generally it is preferred to use binary digits or bits (0 and 1) for representation of the strings. It is termed as gene encoding in a chromosome.

Even though there are a lot of other optimization methods that are being used, we are using genetic algorithm for some obvious reasons. The user holds a certain vantage ground while using this algorithm. In our case, first of all, our objective function is based on a single primary parameter which is distant cost minimization. So, this makes function a single objective function. The accuracy for finding the global optima of the genetic algorithm is much superior that that of other methods. And as the function is singular objective function, this algorithm shows tremendous result. Also, it is easy to understand and implement. this algorithm is flexible to changes to the given functions. By changing the constraints, coordinates, we can actually find unique optimized location. But other methods make that work tough for us because they are not that flexible or adaptive compared to genetic algorithm. Different crossover has made adapting easy for genetic algorithm. Its absence is a drawback for other methods. Also, in future works, using this algorithm will provide us with some advantages because it can be very efficiently mixed when it comes to newer problems and technologies. From the presentation point of view, it can be shown in graphs, matrices, sequences which is very easy to comprehend. This algorithm has a very vast area of application that helps regarding other works that can be done with the help of it.

However, there are some drawbacks in this algorithm too. It's doesn't make it inefficient, but this is what proves that it is not for every type of optimization problem. The major drawbacks are,

- As genetic algorithm works with crossover of data, it takes a lot of time . so we can say the processing time is rather slow compared to other methods,

- The more the complexity, the probability becomes higher that the solution will be inefficient. This algorithm doesn't suit with much complex problems. So, theoretically it can work, but as the problems become more practical, they become more compound. And the efficiency drops.
- This algorithm doesn't require much data, but when it comes to the proper representation of the objective functions and constraints, it might get a bit difficult.
- Accuracy is an issue when it's about coding. Comparing to other methods, the proficiency is a bit low for this algorithm.

3.3 Processing

In our case, we are taking the total population size of the genetic algorithm as 300 and the initial population randomly within upper bound and lower bound. Then we putting our objective function into the algorithm along with the constraint functions. The genetic algorithm provided us with the fittest solution which in our case is the locations with the minimum distance cost. The complete process is shown below in figure 1.3

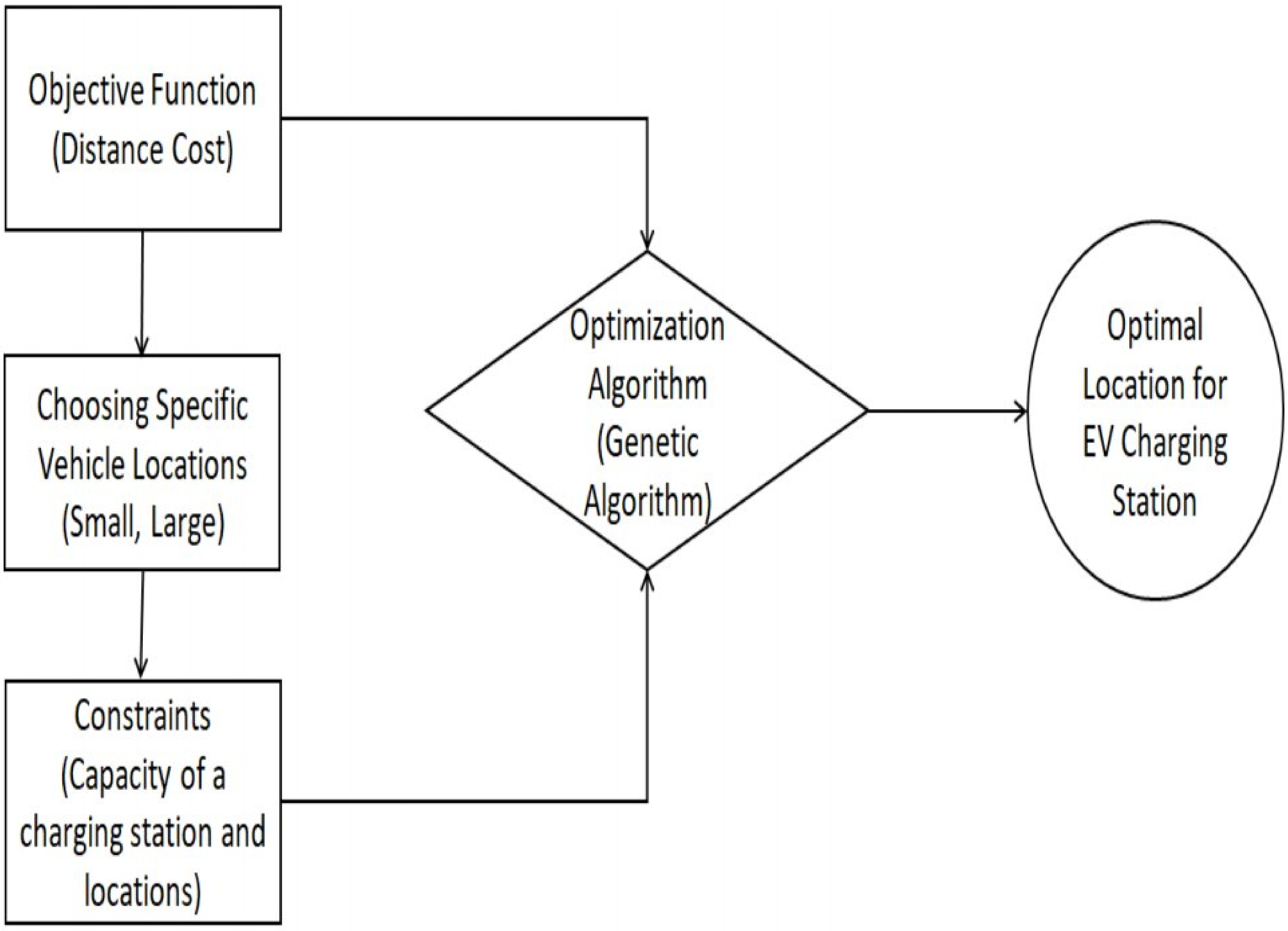

Figure 1.3: Process of Finding the Optimal Solution

Chapter 4

Results

4.1 System description and parameter setting

Our proposed method has been applied to Banani, where we have chosen some random locations and designated those as markets and home. The entire method has been applied for four different scenarios: Red area, Green area, Black area and Purple area. Table 4.1 shows the fixed costs, charging station vehicle capacities and number of selected locations for these four scenarios respectively. Table 4.2 represents the optimal points for these four areas respectively. The number of selected points varies in separate scenarios. The number of vehicles has been chosen as small numbers for ease in simulation. These numbers are chosen randomly. The number of vehicles can be larger. The X and Y coordinate positions are selected by choosing the positions on map of Banani. The coordinates are determined using Matlab.

We have divided the whole Banani Area into four parts. These four parts are marked with four different colors. They are Red, green, black and purple. For the distance, we have decided to take 10 taka per kilometers for our fixed cost. And in every part, we have selected 5 locations apart from the purple one which consists of 4. So, we have 5 locations for red, green and black from where the EV flow will start. And for the purple one, EV flow will start from 4 locations. In red area, the vehicle capacity of the locations are 20 where is for the other three areas, the location capacity is less than 60. So, we can say red area is a place of homes, hospitals in short meaning small places. And the other three areas consist of hospitals, shopping malls etc. referring to large places. Table 4.1 shows this information in a compact manner

Table 4.1: Constraints

Area	Fixed Cost	Number of selected locations	Vehicle capacity
Red	10	5	> 20
Green	10	5	>60
Black	10	5	>20
Purple	10	4	>20

For Table 4.2, it shows the coordinates of the areas that are selected by us specifically. These coordinates will help us understand the locations of the areas on the map clearly. It is important to specify these values, because in this research we are trying to work with a single place (Banani). And this specific coordinates will ease the simulation process and whenever we want to enlarge or divide the whole area into more parts, simply changing these values on the code or the simulation will give adequate results.

Table 4.2: Coordinates of optimal locations

Area	X coordinate point	Y coordinate point
Red	148	109
Green	117	305
Black	186	502
Purple	129	526

4.2 Solution analysis and comparison

14 Genetic Algorithm is applied to find the optimal location for charging electric vehicles according to the proposed model. In this case, the 13 population size is 300 and the initial population is randomly selected number between selected upper bound and lower bound. All codes of genetic algorithm are executed in Matlab 17 on a personal computer with an Intel Core i7 processor and 8 GB RAM. The objective function is 9 determined by assessing the number of vehicles in the selected locations and then the constraints for the algorithm are determined.

Figure 4.1-4.4 shows the resulted fitness values for each generation for red, green, black and purple area respectively. The four scenarios can be compared from these four figures. From the figures, it can be seen that the highest number of generations is required in case of scenario one, the red area. Here more than 300 generations are required for finding the fitness value. In all other scenarios less than 200 generations are required. Even in scenario two, the green area, the number of generations is the least, below 150 generations are required. The best fitness value is 65563.5 and is obtained in the green area.

Figure 4.5-4.8 show the positions of optimal point and selected points on XY Cartesian plane for these four scenarios respectively. And we will see from the figure that, it is very easy to understand the distance from each location to the optimal point. Because the lower the cost, lower the distance from the location to the charging station.

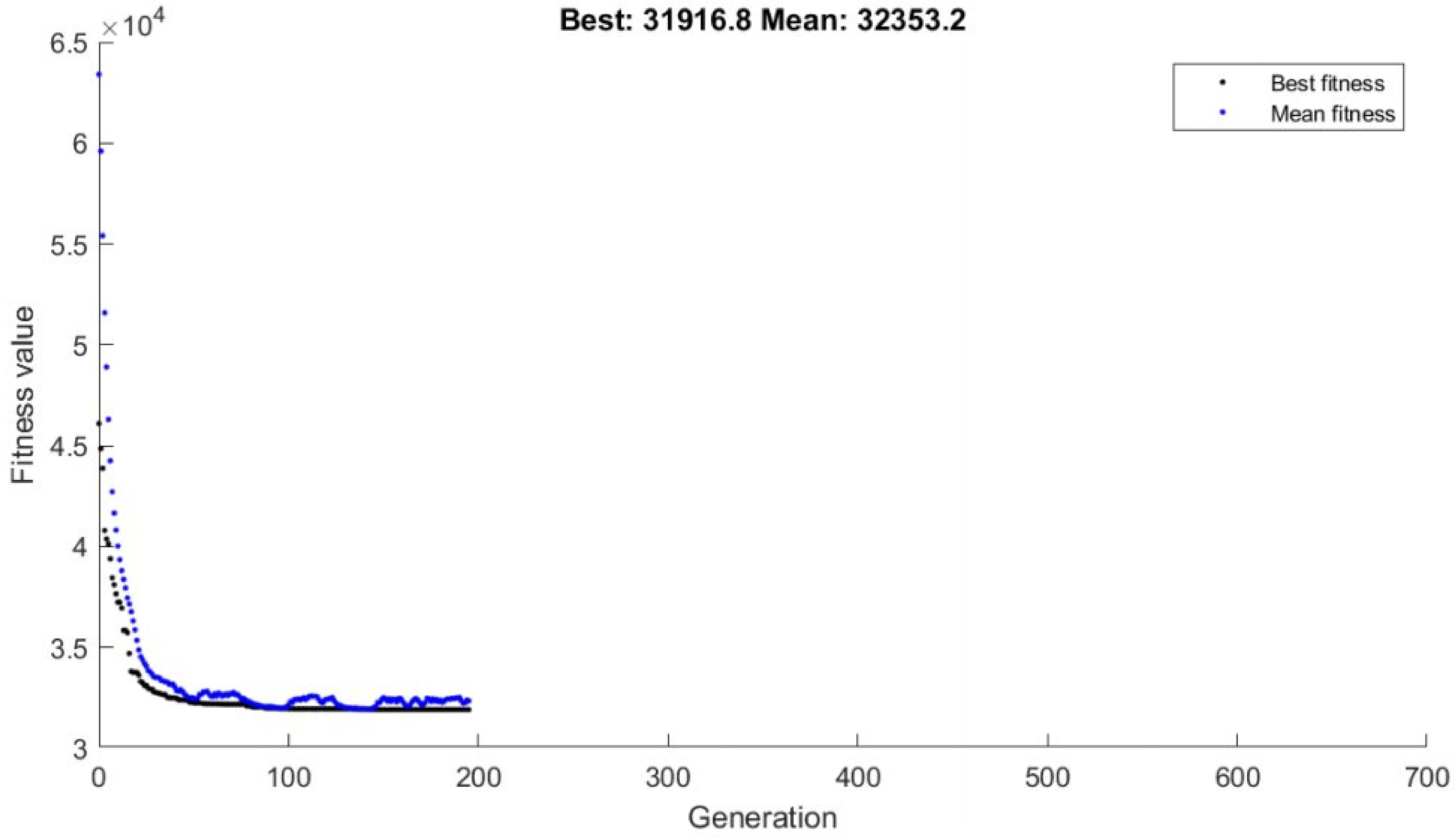

Figure 4.1: Fitness vs generation curve for getting optimal value of red area.

In Figure 4.1 ,we can see more than 150 generations were needed for us to have the fittest value. This figure is for the Red area. And as we can see, the fittest value for this is 31916.8 and the mean value is 32353.2. As we will see, compared to others this is not the best value among the 4 areas.

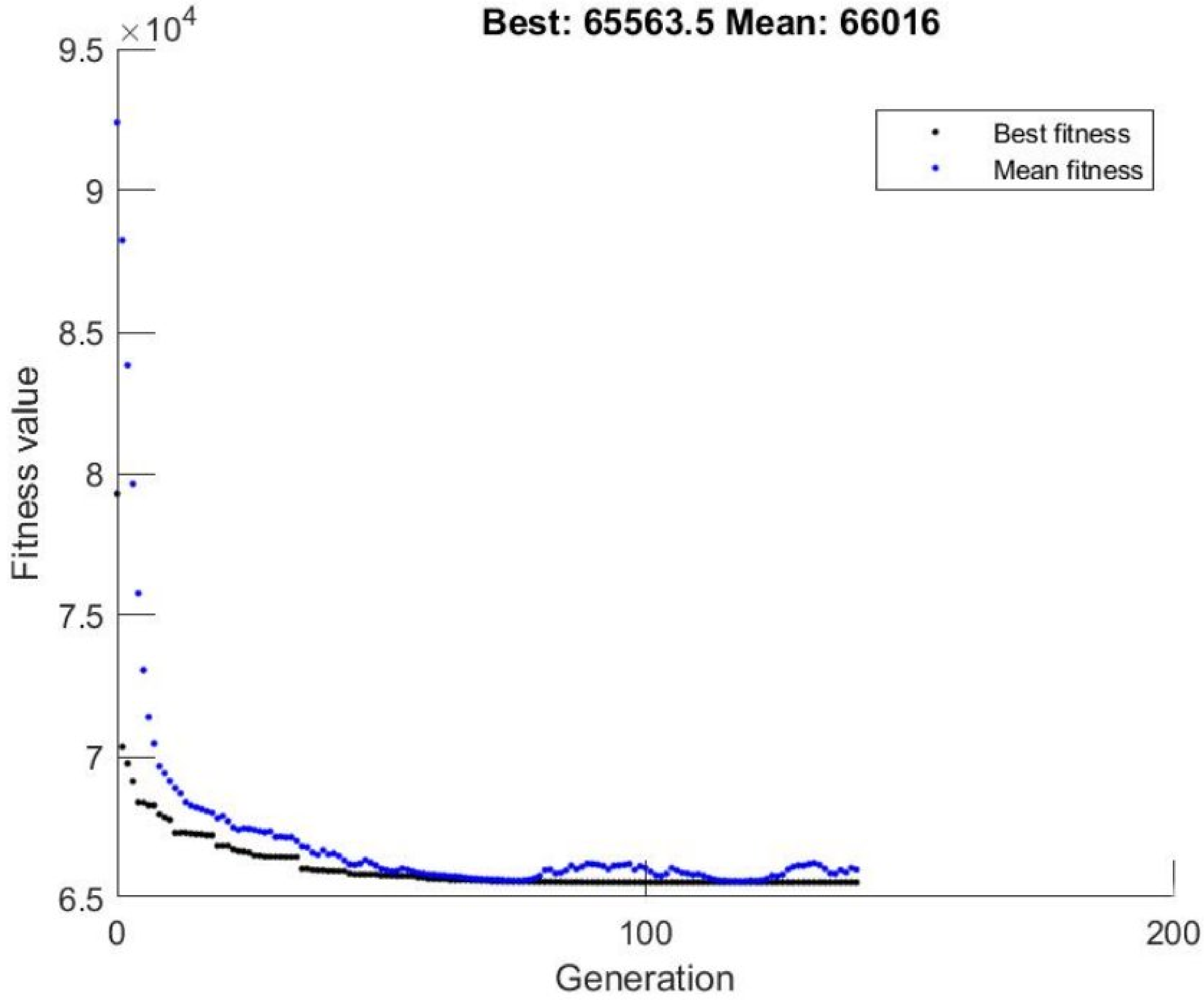

Figure 4.2: Fitness vs generation curve for getting optimal value of green area.

Figure 4.2 is for the Green area. As we can see only 150 generations were needed to find the fittest value for this area. And also, the best value is much higher than the Red are with the value of 65563.5 with a mean value of 660116.

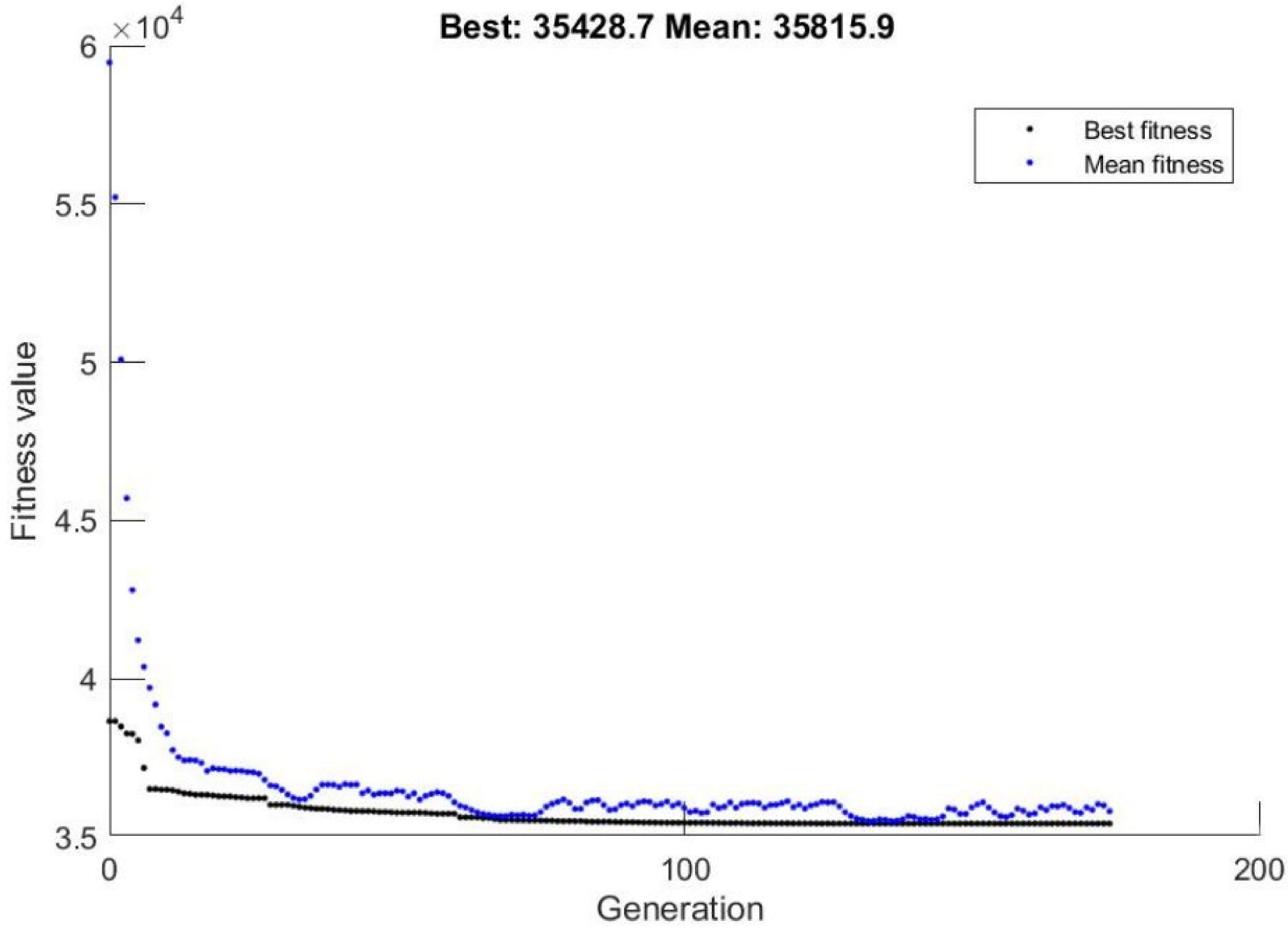

Figure 4.3: Fitness vs generation curve for getting optimal value of black area.

Figure 4.3 represents the Black area. Here, it also takes less than 200 generations to find the fittest value. But the best value is nearly equal to the Red one with a value of 35487.7 with a mean value of 35815.9. And as we can see, this is mediocre compared to the green area.

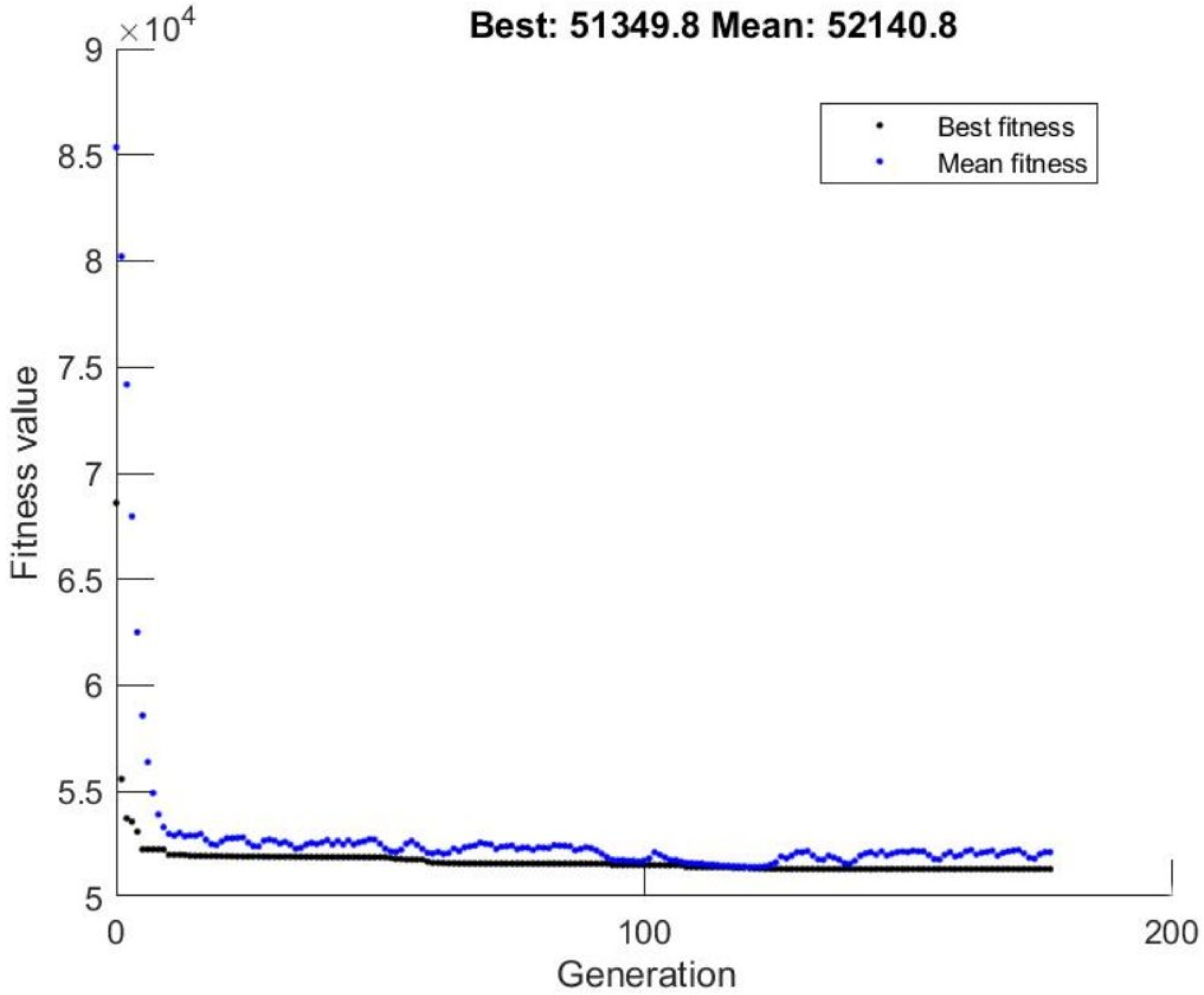

Figure 4.4: Fitness vs generation curve for getting optimal value of purple area.

For Figure 4.4, it represents the Purple area. It also required less than 200 generations finding the optimum value. The best value for this is 51349.8 and means value of 52140.8.

To understand the whole situation, the comparison doesn't actually mean which one is better. These are four different areas with different set of locations. The fittest value represents the optimal locations for that specific area given the number of locations and the capacity of those locations.

Optimal Points for the Areas :

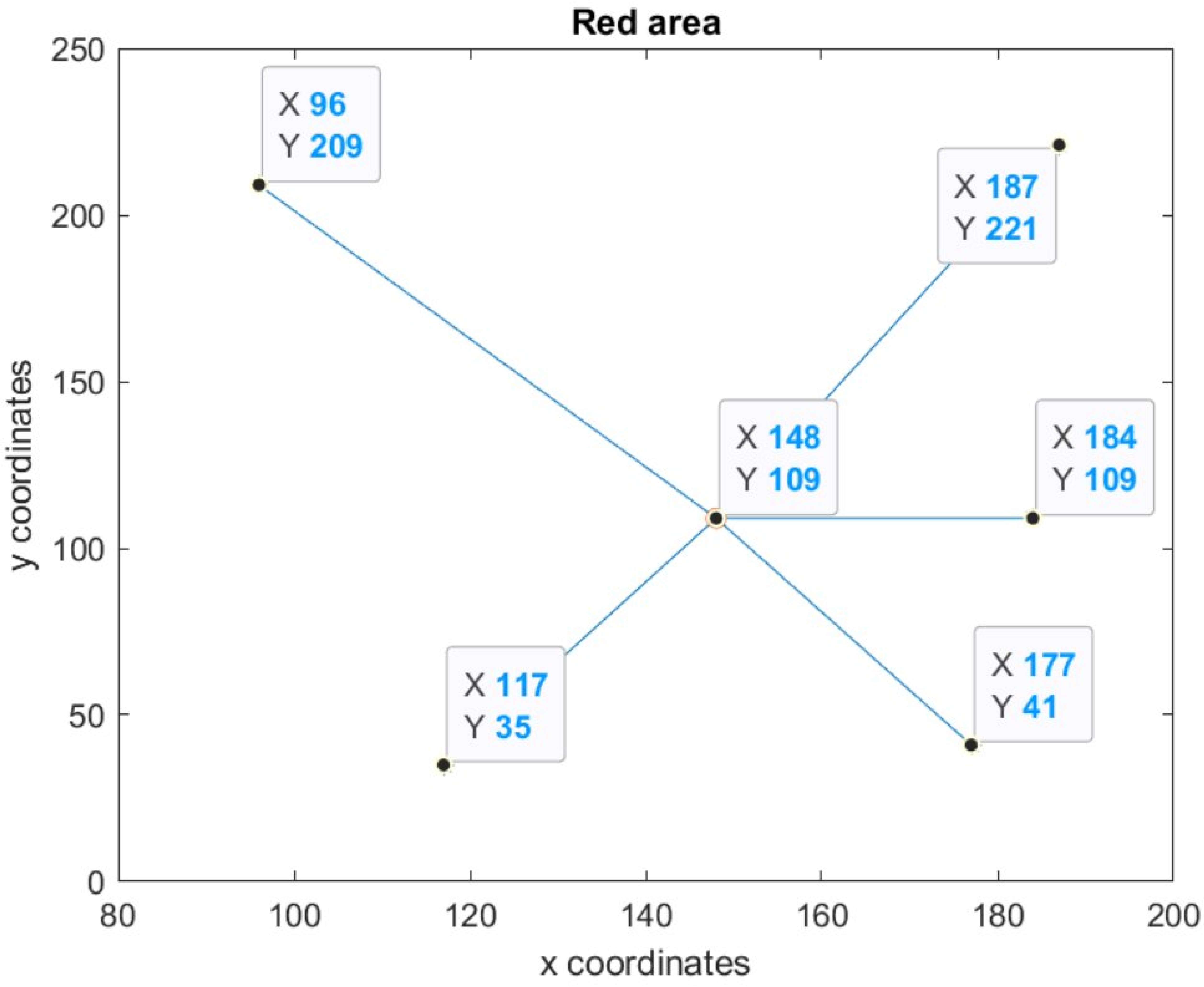

Figure 4.5: Distance from specific location to optimal point (Red area)

As we can see from the figure, the optimal location is provided on the Cartesian plane for 5 different locations. This is for the Red area and as we can see for theis area, the location of the charging station should be X = 148 and Y=109. This actually means for these specific five locations, if EV flow will start, this optimal location is the place where the distance cost will be minimum.

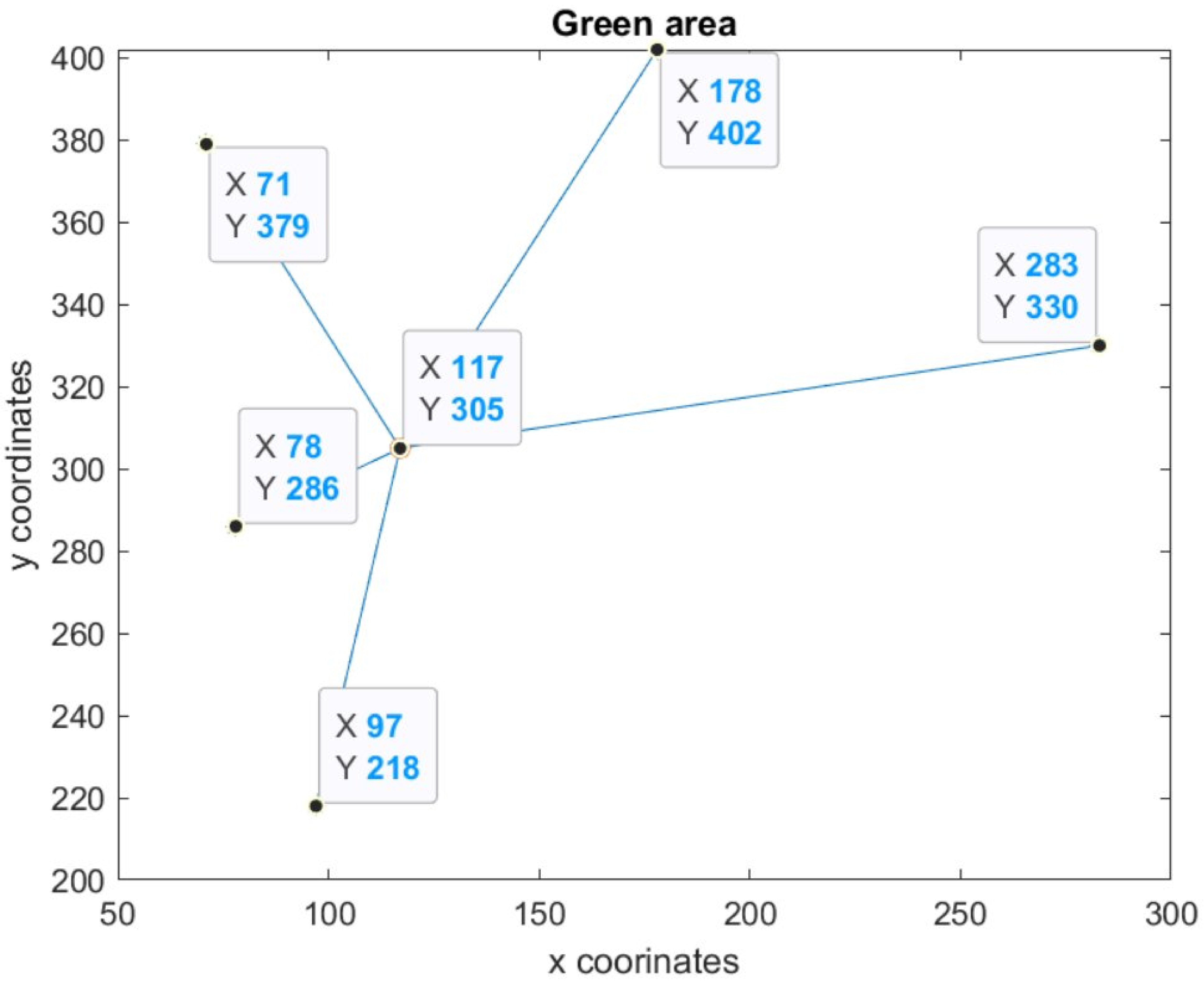

Figure 4.6: Distance from specific location to optimal point (Green area)

As we can see from the figure, the optimal location is provided on the Cartesian plane for 5 different locations. This is for the Green area and as we can see for this area, the location of the charging station should be X = 117 and Y=305. This actually means for these specific five locations, if EV flow will start, this optimal location is the place where the distance cost will be minimum.

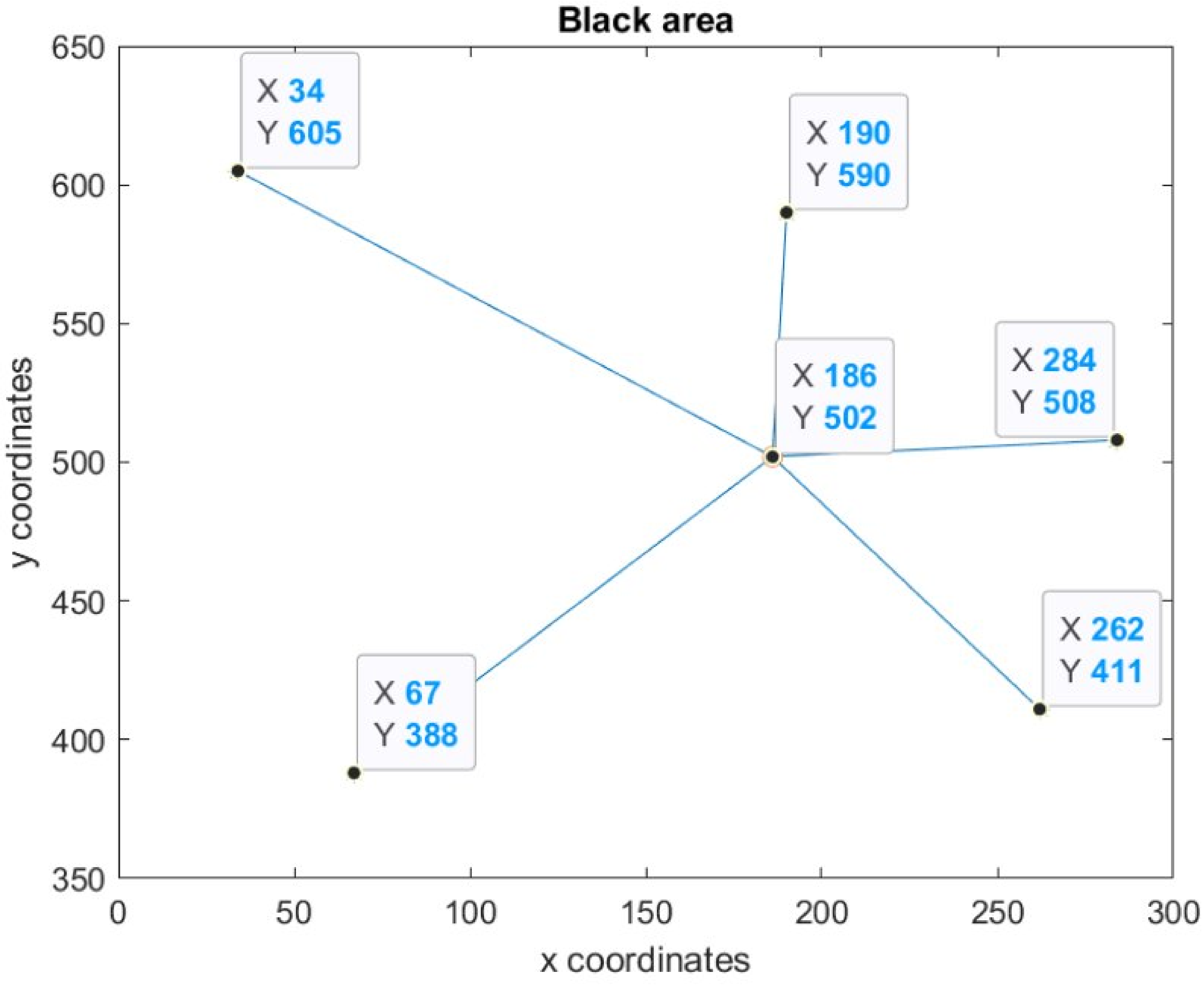

Figure 4.7: Distance from specific location to optimal point (Black area)

And finally from the figure, we see the optimal location is provided on the Cartesian plane for 5 different locations. This is for the black area and as we can see for this area, the location of the charging station should be X = 186 and Y=502.This actually means for these specific five locations, if EV flow will start, this optimal location is the place where the distance cost will be minimum.

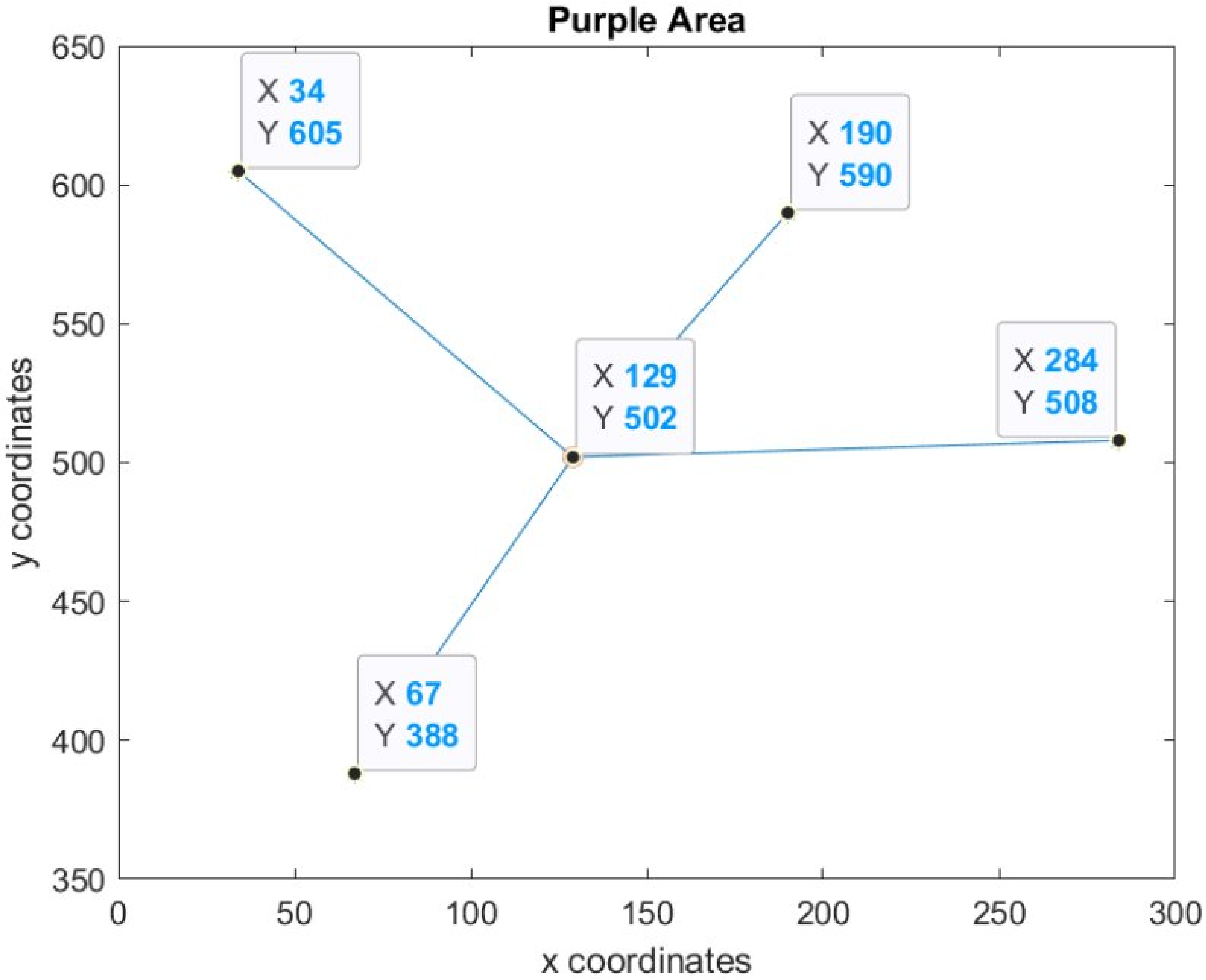

Figure 4.8: Distance from specific location to optimal point (Purple area)

As we can see from the figure, the optimal location is provided on the Cartesian plane for 4 different locations. This is for the purple area and as we can see for this area, the location of the charging station should be X = 129 and Y=502. This actually means for these specific four locations, if EV flow will start, this optimal location is the place where the distance cost will be minimum.

4.3 Cost from specific location to optimal location

The costs for travelling from specific locations to obtained optimal location are also determined in the proposed model for all four scenarios. Figure 4.9-4.12 shows the costs from specific locations to optimal location for red area, green area, black area and purple area respectively. For each area, the minimal cost of travel can be obtained from these figures. The minimal cost can be compared among separate areas and with the change of particular parameter it can be obtained.

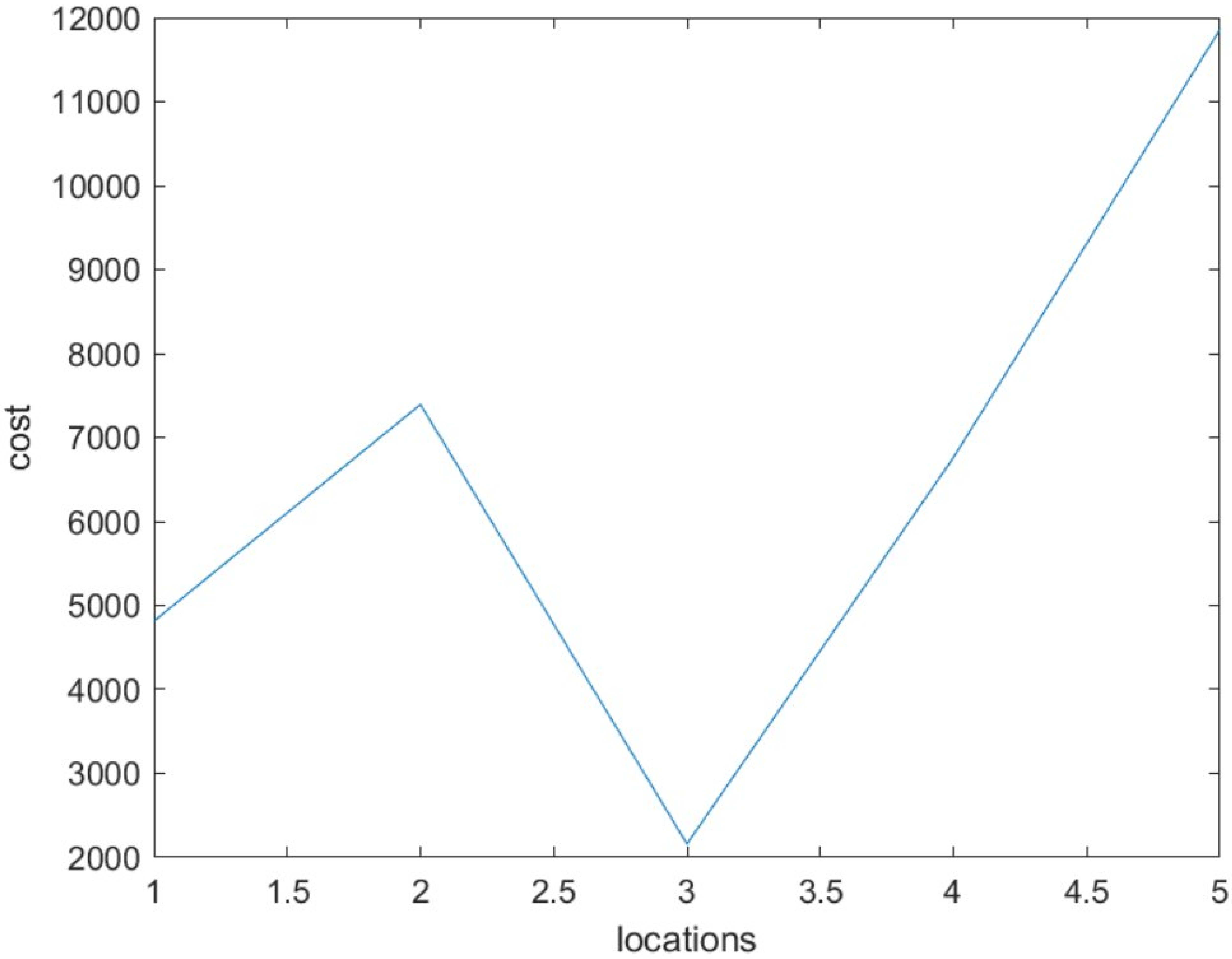

Figure 4.9: Cost from specified locations to optimal location (Red area).

In this figure for the red area, we can see the different distance cost for the 5 locations we have specified. And these costs are varying depending on their distance from the optimal point. For example, for the location number 3, the cost is the lowest as it is closest to the optimal location where the 5th location distance cost is highest as it is furthest from the optimal point. And the amount deficit is pretty noticeable.

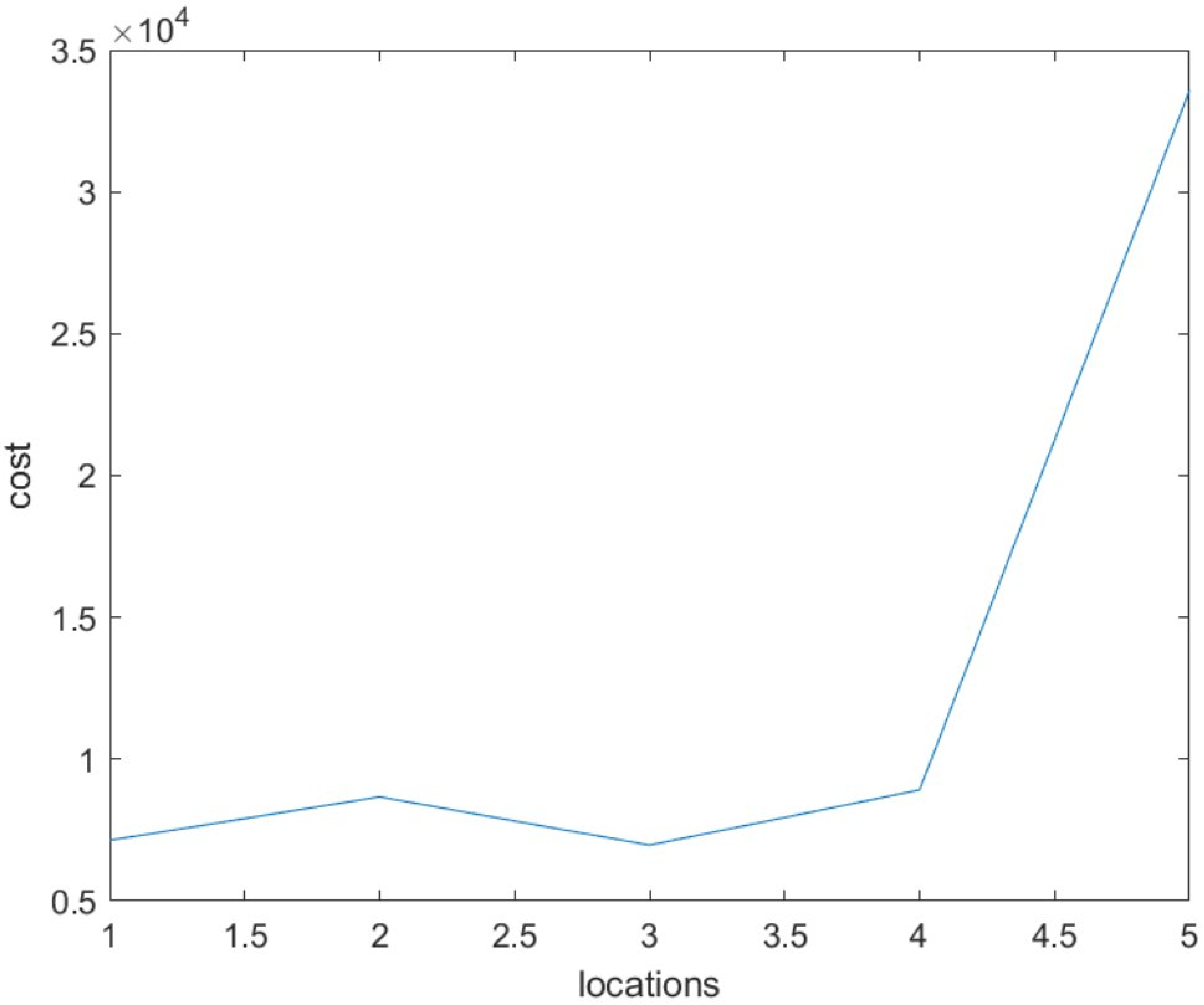

Figure 4.10: Cost from specified locations to optimal location (Green area).

In this figure for the green area, we can see the different distance cost for the 5 locations we have specified. And these costs are varying depending on their distance from the optimal point. For example, for the location number 3, the cost is the lowest as it is closest to the optimal location where the 5th location distance cost is highest as it is furthest from the optimal point. But in this scenario, first four location cost is pretty similar apart from the 5th one. That means the first four has nearly equal distance from the optimal point.

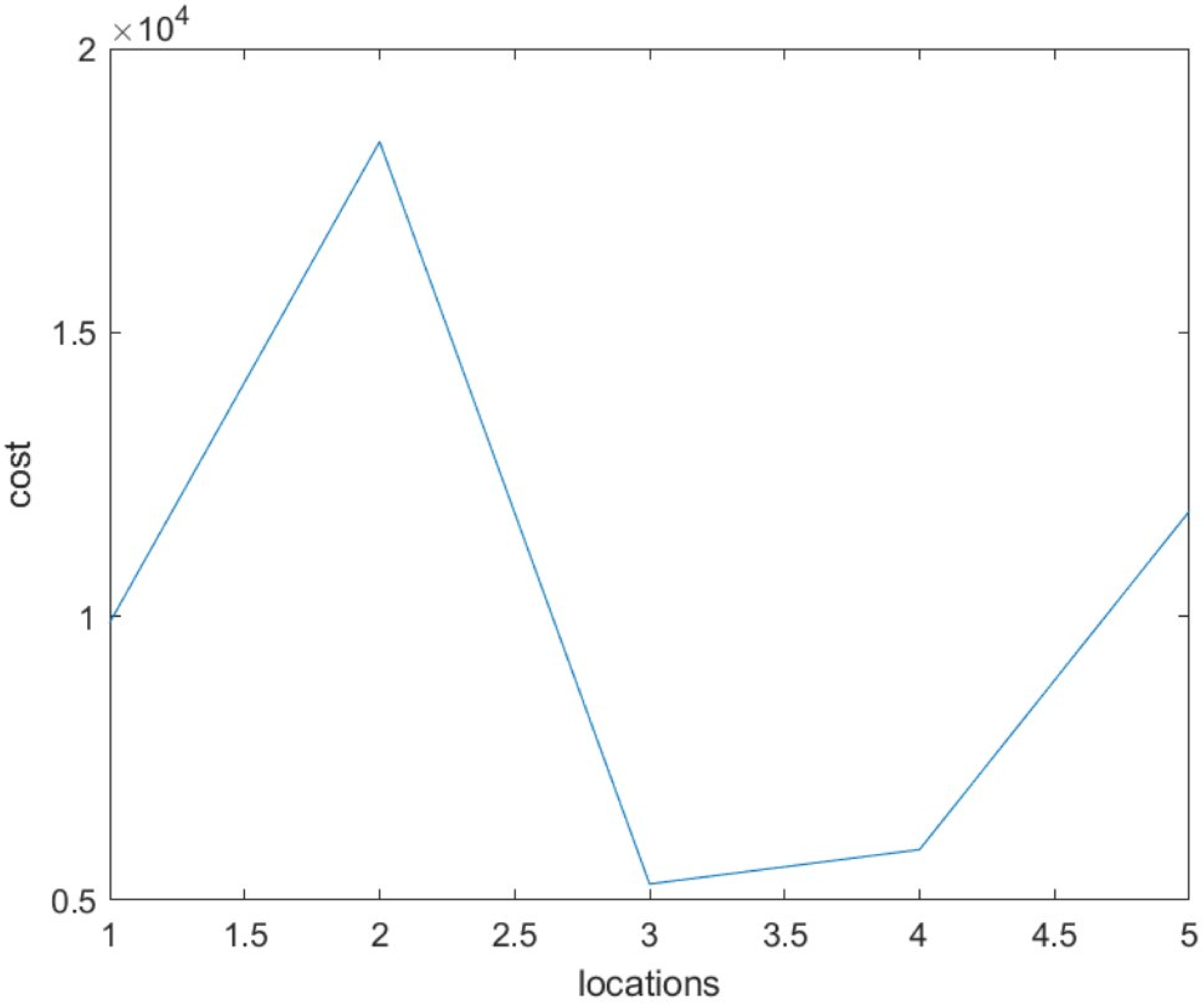

Figure 4.11: Cost from specified locations to optimal location (Black area).

In this figure for the black area, we can see the different distance cost for the 5 locations we have specified. And these costs are varying depending on their distance from the optimal point. For example, for the location number 3, the cost is the lowest as it is closest to the optimal location where the 2nd location distance cost is highest as it is furthest from the optimal point. And also, we can say the distance from location 3 and location 4 are pretty similar from the optimal point.

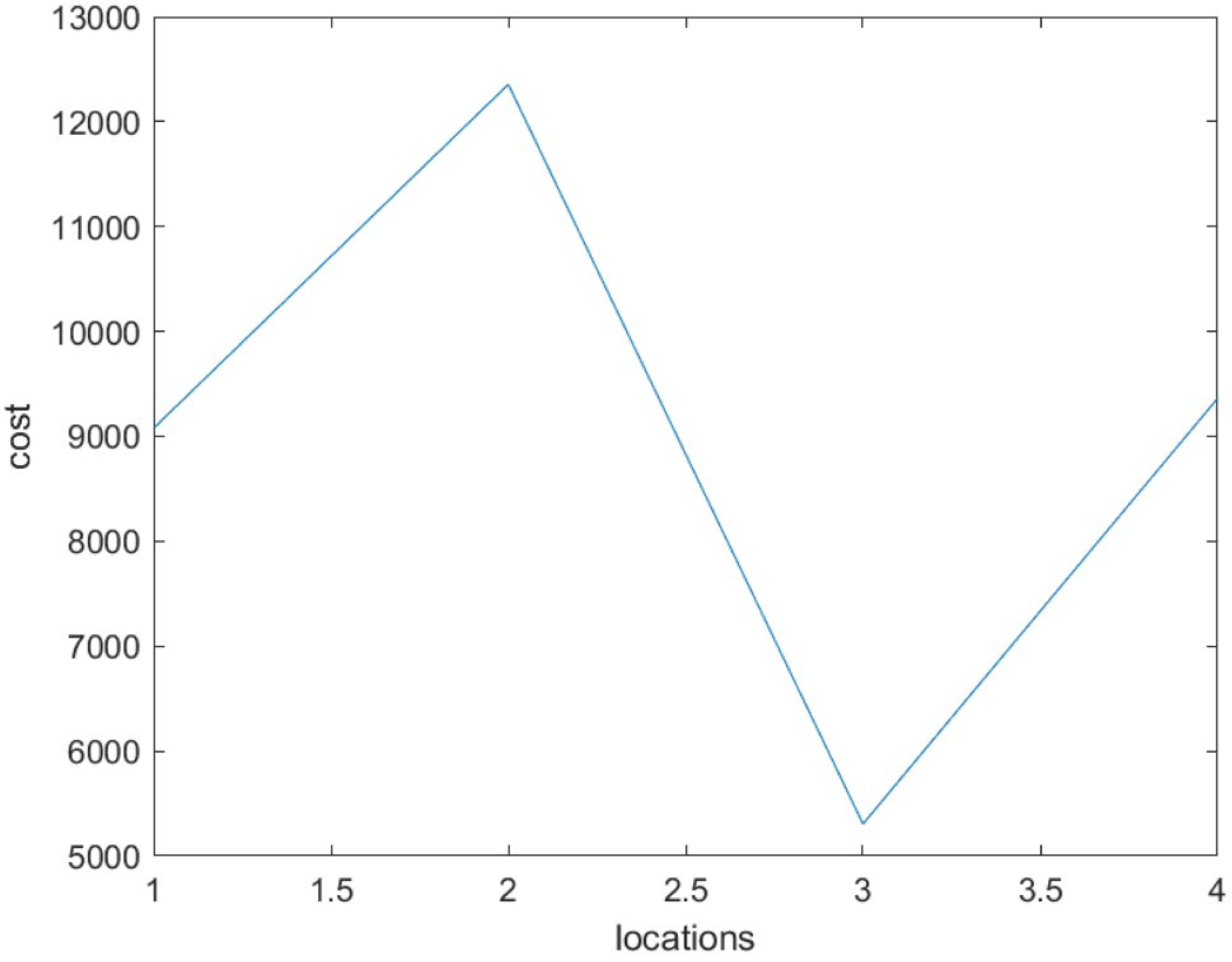

Figure 4.12: Cost from specified locations to optimal location (Purple area).

In this figure for the purple area, we can see the different distance cost for the 4 locations we have specified. And these costs are varying depending on their distance from the optimal point. For example, for the location number 3, the cost is the lowest as it is closest to the optimal location where the 2nd location distance cost is highest as it is furthest from the optimal point. And the amount deficit is pretty noticeable. Also, in case of 4 locations, it doesn't necessarily mean the cost is lower.

Result Representation on Map:

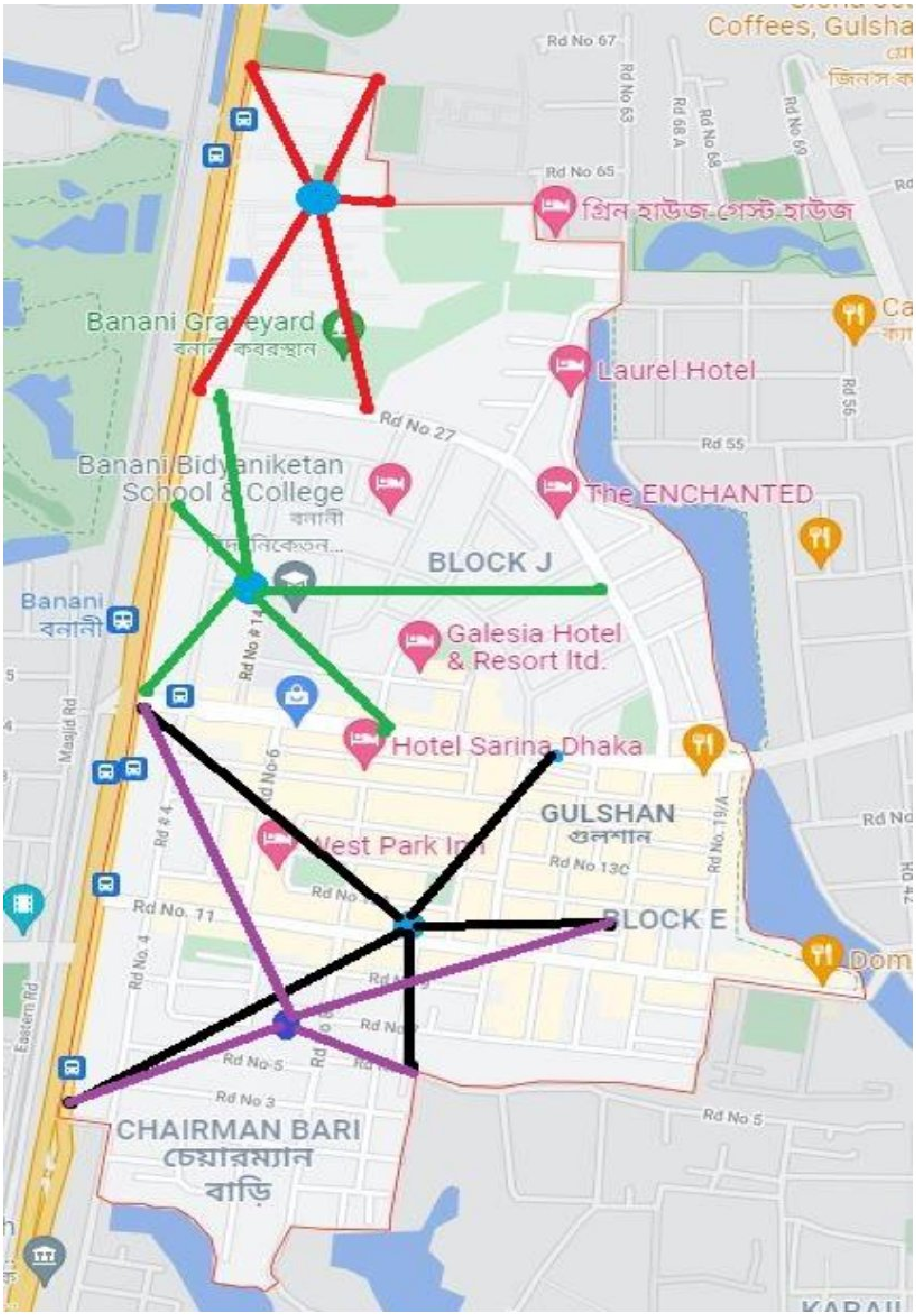

Figure 4.13

This is the map representation of Banani. It represents the 4 locations with color mark. The zones are clearly indicated. As we can see, the zones are well structured in the map. And the locations are well specified from where the EV flow will start. From the red, green and black area, we can say, the distances are the results were shown and it gives more of a practical image which means the implications are pretty accurate. Also, we can see that, the black one and the purple one has 4 common points. This proves a very important point. If we remove one point from the black area, that means, the optimal locations will drastically change based on the other 4 points. It means, it will find the fittest solution for the existing 4 points on the map. So, we can say, the results will be accurate even if we change the locations and or capacity of that location.

Chapter 5

Conclusion

This study explores an algorithm that mimics the complete distribution of charging stations locally. By having the reduction of cost in our mind, we have developed a distance cost model. This model has the minimization of distance cost as primary parameter and capacity as constraints meaning the number of EV can be charged from the charging station and the capacity of certain areas (small and large). And according to the above barriers, this study considers Banani as a research material, and develops a genetic algorithm model. Finally, the appropriate distribution areas of 300 charging stations were calculated by the simulation.

Based on the results we can conclude,

1. The ideal location of the EV charging stations is dependent on the number of places where the EV flow will start, the distance between the areas and charging station numbers.
2. The total cost of the distance is closely related to the number of charging stations and the distance between them.
3. By increasing or decreasing the number of areas, the appropriate areas change significantly depending on the reduced areas.

The major contribution of this study is as follows: First, from a total cost point of view, an appropriate distribution model based on the average cost range was developed to have a basis theoretically, for simulating a complete charging stations distribution. Second, the appropriate areas for charging station are duplicated and replicated using a genetic algorithm with solidified advantages. Lastly, taking Banani as a research tool makes it one of the first projects undertaken by the Bangladesh vision to help establish the EV sector in the country.

While the conclusion of the study will not be enough to provide a comprehensive framework for charging station infrastructure, it will improve the growth of electric vehicles. And in a country like Bangladesh, renewable energy becomes the key to a sustainable future. And EV is a sustainable and very effective solution for the transportation sector. Therefore, this study

Chapter 6

Future Work

In our work, we have taken minimization the distance cost as our primary parameter. We have taken the capacity as our constraint. But this work can be enlarged in much other way. Research can be done by taking different parameters. It can be done constraint was etc. We have mentioned some new avenues for the future work below.

Parameter wise: Lots of parameters can be taken as primary object. Minimization of Total time, Total cost, Environmental impact, Primary power supply etc. this research works for a singular objective. But multi objective function can also be created where multiple parameters are focused at the same time.

Method wise: Different method can be used to create the mathematical model based on the parameters. Such as Stochastic Flow Capturing Location model, Mixed Integer Linear Programming model, a Second-Order Planning model, Haversian model etc.

Constraint wise: We have taken the capacity of the charging stations and the locations as primary constraints. But other constraints will make this research more practical and efficient. Such as uncertainty of demand and degree of satisfaction, power loss and voltage deviation, traffic density, driver's driving pattern, charging station's power, charging time etc.

Charging type wise: A lot of charging type can be used. According to the type, there will be changes. There are different types of charging. For example, fast charging, slow charging, battery swapping, on-board charging, off-board charging etc.

Optimizations Algorithm wise: There are many optimization algorithms. We have used Genetic algorithm because it is efficient when it comes to location planning. And as our objective is single object function, it was the best choice. But there is a lot of other algorithm that we could have used like Sine-Cosine Algorithm, Fire-Fly Algorithm, Particle Swarm Algorithm, Whale algorithm etc. And these algorithm works for both single and multi-objective functions.

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