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RESEARCH ARTICLE

Route Discovery Development for Multiple Destination Using Artificial Ant Colony: Google Map Case Study

Reem J. Ismail[1], Mohammed H. Shukur[1], Samar J. Ismael[2]

[1]Department of Computer Science, Cihan University-Erbil, Kurdistan Region, Iraq, [2]Department of Electromechanical Engineering, University of Technology, Baghdad, Iraq

ABSTRACT

Smart cities need smart application for the citizen not just digital devices. The smart applications will provide a decision-making to users using artificial intelligence. Many real-world services for online shopping and delivery systems were used and attract customers, especially after COVID-19 pandemics, where people prefer to keep social distance and minimize social places visiting. These services need to discover a shortest path for the delivery driver to visit multiple destination and serve the customers. The aim of this research is to develop the route discovery for multiple-destination using ant colony optimization (ACO) algorithm for multiple destination route planning. ACO Algorithm for multiple destination route planning develops the Google Map application to optimize the route when it is used for multiple destination and when the route is updated with a new destination. The results show improvement in the multiple destination route discovery when the shortest path and the sequence order of cities are found. As a conclusion, the ACO Algorithm for Multiple destination route planning simulation results could be used with Google Map application and provide an artificial decision for the citizen in Erbil city. Finally, we discuss our vision for future development.

Keywords: Multiple destination route discovery, Google Map application, the shortest path, ant colony optimization algorithm

INTRODUCTION

Smart cities use intelligent systems for decision-making and optimization to provide city management and citizens services. There are many applications for smart city such as: transportation, healthcare, environment, and public safety.[1]

To have a city with “smart” infrastructure, it needs to develop three layers of “smartness” as follows: [2,3]

- The application layer for end users that interact directly with the user and consists of the deployment of smart applications
- The service-oriented middleware layer that processes big data and real-time analysis that support smart city applications
- Data acquisition layer base on sensors connected in networks to gather data.

  Figure 1 shows three layers for smart city.[2]

Route planning methods for multiple destination have been applied to real-world applications and needed in smart cities services such as: delivery service around the city for restaurants, online shopping needs multiple shipping destinations, route planning for companies and delivery agents, and generating navigation map to help the tourist to visit multiple destination.[4,5]

Route planning can be classified mainly into: single destination route planning and multiple destinations route planning. Single destination route planning is based on finding a single destination path from the source, and usually, finding the shortest path is the main target. Dijkstra’s algorithm is the most algorithm for finding the shortest path from the source node to the destination node, where the algorithm creates a tree using the weighted graph to all other nodes also the depth first search and the k-shortest path algorithms are used for optimizing shortest path in networks.[6-9]

In multiple destination route planning, traveling salesman problem (TSP) is a one of the scheduling and planning methods that visit the multiple destinations, where a set of destinations

Corresponding Author:
Reem J. Ismail, Department of Computer Science, Cihan University-Erbil, Kurdistan Region, Iraq. E-mail: reem.jafar@cihanuniversity.edu.iq

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are represented as nodes in a graph. The aim of TSP is to visit each node exactly once with the shortest path.[10]

Figure 2 is an example of multiple destinations which are office and plaza to deliver several packages. Here, there are two different routes: route (a), which goes to the plaza first and route (b), which goes to the office first, the best path is considered when satisfy the user requirements such as reduce travel cost and fuel consumption.[11]

First, ant colony optimization (ACO) is used to solve optimization problems; then, it is developed to be used for artificial intelligence applications. ACO is based on behavior of ants for finding food. During the ant walk, it deposits pheromone to find their route and the density of pheromone deposition increases when the ant returns back to the source point with food. Many ants will travel on different paths and the optimal path will be found when it has the maximum pheromone deposition.[12]

The main contribution of this work is as follows:

- Develop a smart service for Erbil city citizen to find shortest path with multiple destination
- Enhance Google Map application as a navigation application to have decision-making.

The remainder of this paper is organized as follows: the most recent related works are presented in section (II); then, multiple destination for route discovery challenges is explained in section (II). Furthermore, in section (IV), we describe an important application and service relate to multiple destination route discovery planning which is Google Map. Section (V), (VI), and (VII) explain and implement an artificial algorithm to develop route discovery in Erbil city when the shortest path is found. Finally, work conclusion and future work are discussed in section (VIII).

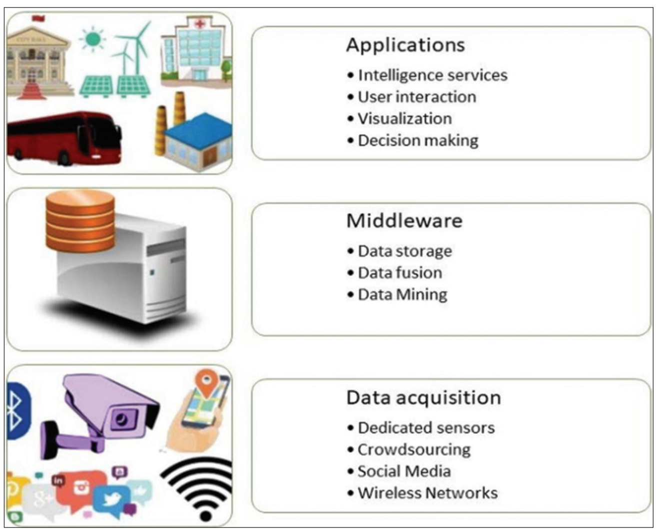


Figure 1: Layers of smartness

LITERATURE REVEIW

Single destination route planning algorithms have more research publications relate to multiple destination route planning algorithms. In the literature, the most recent multiple destination route planning algorithms are explained.

Huang *et al.*,[11] proposed an algorithm by implementing the dynamic graph miner for multi-destination route to plan the route and measure its cost and time according to user requirements and deadlines with efficient optimizing.

Zhuang *et al.*,[13] proposed an algorithm for the mobile robot when visiting multiple destinations using a simulated grid map for the environment with the obstacle values. Q-learning algorithm is implemented to find the optimal path of multiple destinations for mobile robots with minimum obstacles. The results of the algorithm shown a reduce in path length when using global planning compared to others.

Asaduzzaman *et al.*,[14] modified Dijkstra algorithm with the minimal weight for multiple destinations in indoor applications, where Dijkstra algorithm is modified to implement multiple destinations instead of single destination. The implementation starts from the source node to visit the first nearest destination that becomes the new source node again to the next nearest destination, and so on until all destination nodes are visited.

Abeer *et al.*,[15] proposed an algorithm to serve multiple destination requests to plan the route considering real-time traffic conditions and the free parking places in the city to find the minimum time for the driver to travel. The results of the algorithms shown the best performance compared to others.

Eric *et al.*,[16] proposed a strategy named Cluster-Based Approximation Strategy, to cluster the destinations into several destination clusters, to determine the fastest visiting order from specified multiple destinations. Inside the destination

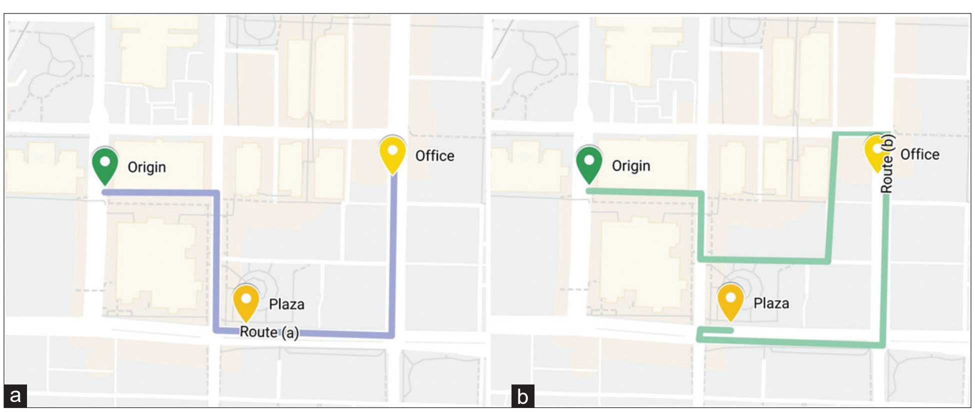


Figure 2: An example of multiple destination delivery problem: (a) Visit the plaza first and (b) Visit the office first.

cluster, the proposed algorithm will choose the destination with the minimum travel time then calculate the local optimal path for all destination nodes in the same cluster.

Table 1 presents an overview for multiple destination route discovery protocols.

ANALYZING MULTIPLE DESTINATION ROUTE DISCOVERY PROTOCOLS

The most two important challenges for multiple destination route discovery protocols are as follows: mapping model and route planning. The mapping model is used to represent the source node and multiple destination nodes such as graph, while route planning is needed to serve the customer's order within optimal path.

Mapping Model

One of the challenges that face multiple destination route discovery protocol is how to represent a model for the protocol. In[11] they use graph model as a grid for each route, as shown in Figure 3, where the route is represented as 3*3 grids. Accordingly, this route is divided into five segments which are {p1, p2}, {p3, p4, p5, p6}, {p7, p8}, {p9, p10}, and {p11, p12, p13, p14}. The aim of grid design is to calculate travel speed, traffic flow, and travel time for each road segment.

Table 1: Overview of related works for multiple destination route discovery

Authors	Multiple Destination Route Discovery Protocol
Huang *et al.*,[11] 2021	Satisfy user multiple requirements relate to cost and time with deadlines
Zhuang *et al.*,[13] 2021	Consider obstacles in the environment when the mobile robot finds the optimal path of multiple destinations
Asaduzzaman *et al.*,[14] 2021	Consider indoor environment to find the shortest path for multiple destination like in warehouses or libraries when a customer needs multiple items to search
Abeer *et al.*,[15] 2019	Consider real-time traffic conditions in the city and free parking places for drivers
Eric *et al.*,[16] 2011	Use cluster strategy to cluster the destinations into several destination clusters
Proposed artificial ant colony for multiple destination route discovery protocol	Consider artificial ant colony and real-time route discovery for multiple destination when a new destination will be available with the shortest path

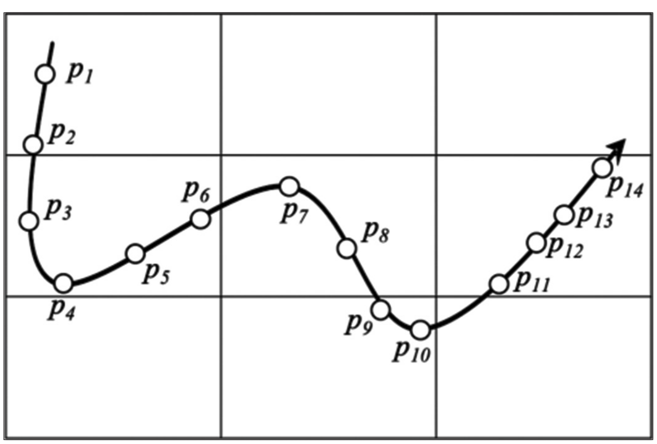


Figure 3: An example of 3*3 grid for route

Route Planning for Multiple Destination

Another challenge that faces multiple destination route discovery protocols is how to find the route plan to multi-destination.

In[11] they use a dynamic graph generator, where the path is generated from multi-weight dynamic directed graph. The method is implemented using directed graph with map information; then, the travel costs of different time slots are calculated by going through all the edges and vertices.

Google Map Application for Multiple Destination Route Planning

In this section, we explain the most application that is used for route planning, which is Google Map application. Many citizens use Google Map application as a navigation application around the city. Google Maps are a free online graphic map service that Google provides it in 2005.[17] This service provides several information such as: roadmaps, a distance between two or more locations, traffic conditions, and route for traveling by foot, car, and bike.[18]

We choose Google Map for Erbil city as case study. Erbil is the capital city of Kurdistan Region – Iraq. Erbil city has five main roads which are as follows: Kasnazan Road, Masif Road, Bahirka Road, Kirkuk Road, and Mosul Road, as shown in Figure 4.[19]

Google Map application is used to find the route form source location to one destination or multiple destination. We identified a problem in Google Map application when it is used for multiple destination, which is that the route plan is not optimized with the shortest path, the user needs to select manually the multiple destination in an order from the near location to far location from the source to give the shortest path.

Figure 4: Google map for Erbil city

THE PROPOSED DEVELOPMENT FOR MULTIPLE DESTINATION ROUTE PLANNING

In *ACO Algorithm for multiple destination route planning*, ten artificial ants will generate different routes. All the routes will be found, and then, the best route which has the minimum cost will be chosen and used. During the ant walk forward and backward, the pheromone trails are updated by deposition and evaporations. Algorithm (1) is the pseudocode of the *ACO Algorithm for multiple destination route planning*.

We assume that there is a fleet of vehicles and drivers that are available, and each driver is responsible for a specific region in the Erbil city. In our proposal, we assign one driver to cover the delivery for each main roads in the city. First, the multiple destination must identify which region it belongs to then, the driver region will visit all destination.

In algorithm (1), the initial parameters represent: m is number of ants, e is evaporation coefficient, α is the effects of ants' sight, β is trace's effect, and ρ is common cost elimination.

During multiple destination route planning, a new destination may be added to the system, where the system must consider the update in route. In this case, the system is updated with new destination when it gets the information about the new destination relate to its location and distance relate to other destinations. The information of cities is real information which are taken from Google Map application for Erbil city.

Algorithm (1): *ACO Algorithm for multiple destination route planning*

Input: Number of cities (c), distance between cities (d), and number of regions in the city (n)

Output: Minimum total distance and shortest route plan

Begin
1. Initial Parameters:
2. m=10, e=0.15, α=1, β=4, ρ=0.97
3. For each region in the city do
4. For each ant do
5. Forward ant and generate place for it Select next node using probabilistic solution generation

Add the selected node to the route Calculate the cost (distance) of ants' touring

Add ant tour cost to the tour set

Update the route information by updating pheromones (evaporation and deposition process)

6. If new destination is added
7. Update the route information by getting the location of the new city and added to the specified region and go to step 4
8. Determine the best route from tour set

End

IMPLEMENTATION AND SIMULATION

In this section, we present the implementation of *ACO Algorithm for multiple destination route planning* and Google Map multiple destination in Erbil city then evaluate them, using MATLAB R2018a (9.4.0.813654).

On Kasnazan Road, different routes relate to multiple destination of cities are implemented, where the cities are: Hawleri New, Shariy ANDAZYARAN, Hewa City and Havalan, when Family Mall will be considered as the source location. The information relate to the total distance in km form source to multiple destination is taken form Google Map application of Erbil city.

Figures 5–7 shows the route for path 1, path 2, and path 3 as an example using multiple destination, respectively.

As shown in Table 2, Google Map application will find different total distance depending on the sequence of the input destination from the user and will not give or suggest the shortest path to visit all destinations.

Figure 8 shows the route plan when new destination is added to the multiple destination.

Using *ACO Algorithm for Multiple destination route planning,* the cities information relate to location and distance in km are input to MATLAB as a simulation coordinate (x, y). Figure 9 shows the coordinates of the cities in Figures 5–7 and 10, which shows the coordinates of

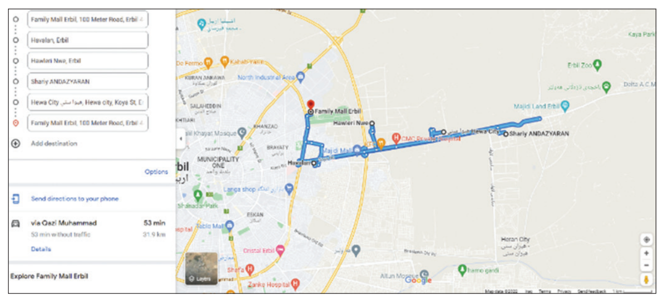


Figure 5: Path 1 route from Google map

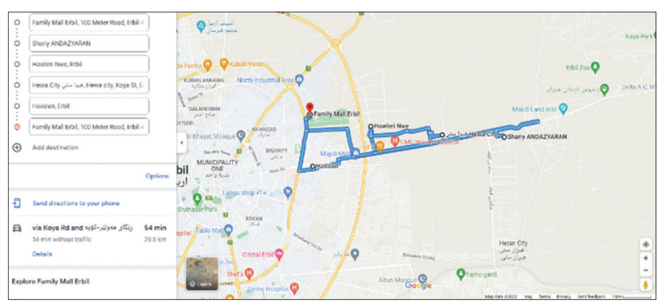


Figure 6: Path 2 route from Google map

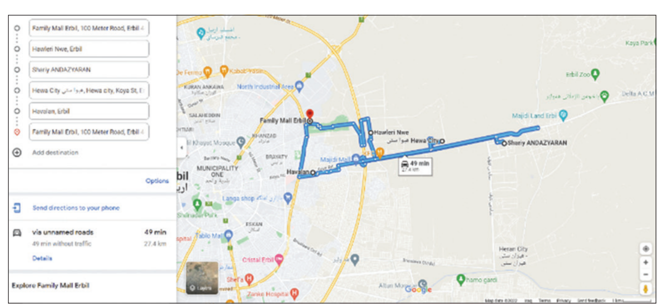


Figure 7: Path 3 route from Google map

the cities in Figure 8 when new destination is added. Note for example, that the source node of Family Mall is located at coordinate (2, 4) and the new destination is located at coordinate (16, 0).

On Masif Road, different routes relate to multiple destination of cities are implemented, where the cities are: Italian City 2, Shaways and Zin city when Family Mall will be considered as the source location. The information relate to the total distance in km form source to multiple destination is taken form Google Map application of Erbil city.

Table 2: Compares different route for multiple destination of cities in Erbil using Google map

Route	Multiple destination route	Total Distance (km)
Google Map path 1	Havalan, Hawleri New, Shariy ANDAZYARAN, Hewa City	31.9
Google Map path 2	Shariy ANDAZYARAN, Hawleri New, Hewa City, Havalan	29.6
Google Map path 3	Hawleri New, Shariy ANDAZYARAN, Hewa City, Havalan	27.4

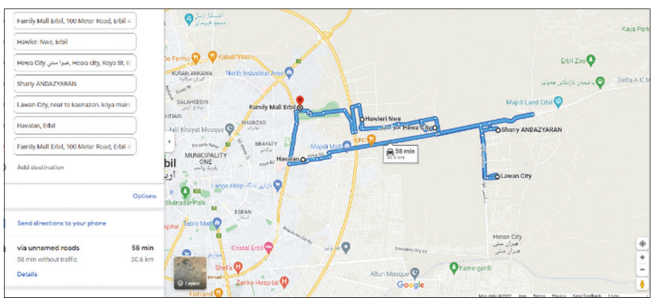


Figure 8: Route update when new destination is added from Google map

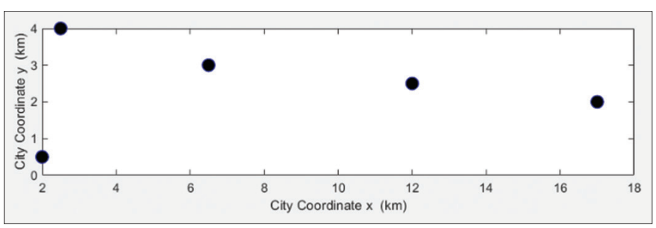


Figure 9: City Coordinates of source and multiple destination

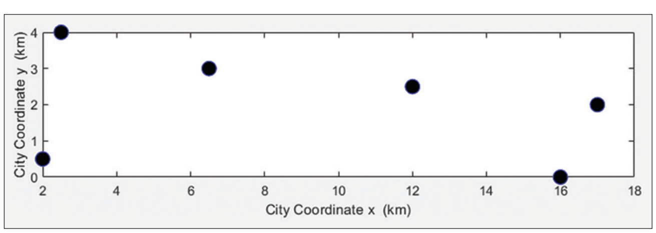


Figure 10: City Coordinates of source and multiple destination when new destination is added

Figures 11–13 shows the route for path 5, path 6, and path 7 as an example using multiple destination, respectively. As shown in Table 3, Google Map application will find different total distance depending on the sequence of the input destination from the user and will not give or suggest the shortest path to visit all destinations.

Figure 14 shows the coordinates of the cities in Figures 11–13.

RESULTS AND EVALUATION

ACO Algorithm for Multiple destination route planning results are shown in Figures 15 and 16. Figure 15 shows the minimum path for five cities of Figure 9 of minimum total length of 26 km. Figure 16 shows the minimum path for six cities of Figure 10 of minimum total length of 30 km.

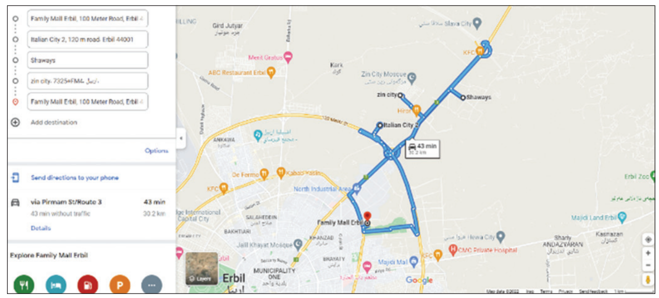


Figure 11: Path 5 route from Google map

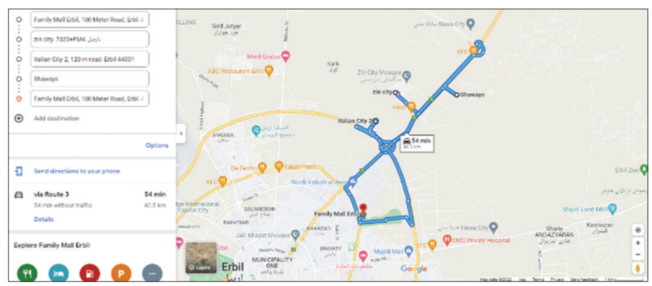


Figure 12: Path 6 route from Google map

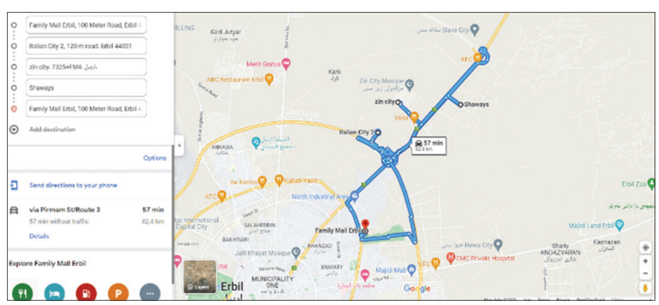


Figure 13: Path 7 route from Google map

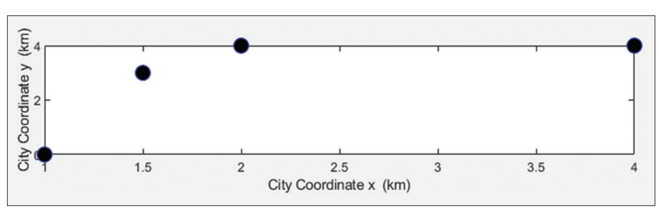


Figure 14: City Coordinates of source and multiple destination

Table 3: Compares different route for multiple destination of cities in Erbil using Google Map

Routes when the source node is family mall	Multiple destination route	Total distance/ km
Google Map path 5	Italian City 2, Shaways, Zin city	30.2
Google Map path 6	Zin city, Shaways, Italian City 2	40.5
Google Map path 7	Italian City 2, Zin city, Shaways	42.4

ACO Algorithm for Multiple destination route planning is evaluation and compared with Google Map route with multiple destination. Table 4 shows the comparison of ACO algorithm according to the sequence of visiting multiple destination relate to the five cities that are located at Kasnazan Road Region in Erbil, Figures 5–7. As shown in Table 4, *ACO Algorithm for Multiple destination route planning* has total length of 26 km which is the minimum distance compared to others also the algorithm presents the sequence order of the visiting cities in the route of path 4. Table 5 shows the error percentage of route length for Google MAP application results compared to *ACO Algorithm for Multiple destination route planning* result.

Figures 17 and 18 show the output results for Figures 15 and 16, respectively, when all routes are generated for the artificial ants in *ACO Algorithm for Multiple destination route planning*.

Figure 19 shows the minimum path for four cities of Figure 14 of minimum total length of 27.1 km.

ACO Algorithm for multiple destination route planning is evaluation and compared with Google Map route with multiple destination. Table 6 shows the comparison of ACO algorithm according to the sequence of visiting multiple destination relate to the four cities that are located at Masif Road Region in Erbil, Figures 11–13. As shown in Table 6, ACO Algorithm for Multiple destination route planning has total length of 27.1 km which is the minimum distance compared to others also the algorithm presents the sequence order of the visiting cities in the route of path 8. Table 7 shows the error percentage of route length for Google MAP application results compared to ACO Algorithm for Multiple destination route planning result.

Figure 20 shows the output results for Figure 19 when all routes are generated for the artificial ants in ACO Algorithm for multiple destination route planning.

The ACO algorithm for multiple destination gives optimal path when the shortest path is found and the sequence order of visiting cities is discovered around the city returning back to the source location. The ACO algorithm considers one of the important factors when the multiple destinations are available is that the source location needs to be reached with minimum route from last destination. Retuning back from last destination to source location is found with shortest path. For example, in route plan for path 4, when last destination is Havalan and the source location is Family Mall the shortest route that is considered in the total route plan. Furthermore,

Table 4: Compare ACO algorithm for multiple destination of cities in Erbil with Google map

Route	Multiple destination route	Total distance (km)
Google Map path 1	Havalan, Hawleri New, Shariy ANDAZYARAN, Hewa City	31.9
Google Map path 2	Shariy ANDAZYARAN, Hawleri New, Hewa City, Havalan	29.6
Google Map path 3	Hawleri New, Shariy ANDAZYARAN, Hewa City, Havalan	27.4
ACO *Algorithm for Multiple destination route planning path 4*	Hawleri New, Hewa City, Shariy ANDAZYARAN, Havalan	26

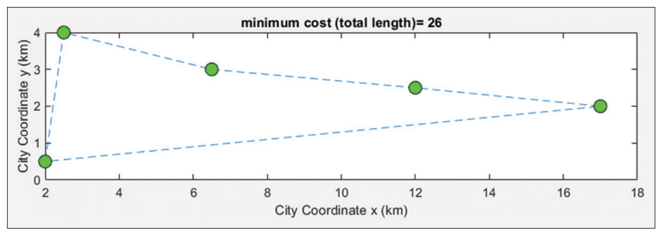


Figure 15: ACO Algorithm for multiple destination route planning for five cities

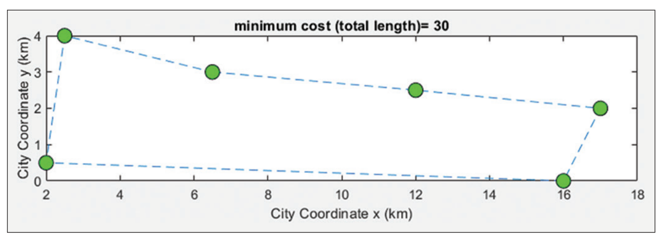


Figure 16: ACO Algorithm for multiple destination route planning for six cities

32	26	27	28	27	26	32	28	29	29
26	26	26	29	26	26	26	26	26	26
26	26	26	26	26	26	26	26	26	26
26	26	26	26	26	26	26	26	26	26
26	26	26	26	26	26	26	26	26	26
26	26	26	26	26	26	26	26	26	26
26	26	26	26	26	26	26	26	26	26
26	26	26	26	26	26	26	26	26	26
26	26	26	26	26	26	26	26	26	26
26	26	26	26	26	26	26	26	26	26

Figure 17: Different routes cost for ten artificial ants for five cities

Table 5: The error percentage of Google MAP compared to the result of ACO Algorithm for multiple destination route planning with five cities

Routes when the source node is Family Mall	Multiple destination route	Total Distance/km	Error Related to ACO=26
Google Map path 1	Havalan, Hawleri New, Shariy ANDAZYARAN, Hewa City	31.9	23%
Google Map path 2	Shariy ANDAZYARAN, Hawleri New, Hewa City, Havalan	29.6	14%
Google Map path 3	Hawleri New, Shariy ANDAZYARAN, Hewa City, Havalan	27.4	5%

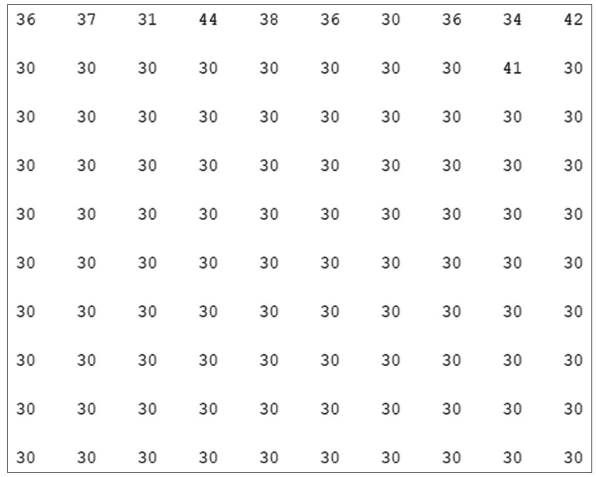
Table 6: Compare ACO algorithm for multiple destination of cities in Erbil with Google map

Routes when the source node is Family Mall	Multiple destination route	Total distance/km
Google Map path 5	Italian City 2, Shaways, Zin city	30.2
Google Map path 6	Zin city, Shaways, Italian City 2	40.5
Google Map path 7	Italian City 2, Zin city, Shaways	42.4
ACO Algorithm for Multiple destination route planning path 8	Shaways, Zin city, Italian CiVty 2	27.1

Table 7: The error percentage of Google MAP compared to the result of ACO *Algorithm for Multiple destination route planning* with four cities

Routes when the source node is Family Mall	Multiple destination route	Total Distance/km	Error Related to ACO=27.1
Google Map path 5	Italian City 2, Shaways, Zin city	30.2	12%
Google Map path 6	Zin city, Shaways, Italian City 2	40.5	50%
Google Map path 7	Italian City 2, Zin city, Shaways	42.4	57%

in route plan for path 8, when last destination is Italian City 2 and the source location is Family Mall the shortest route that is considered in the total route plan. Finally, Figures 21 and 22 shows the comparison between ACO algorithm for multiple destination route planning with Google Map routes plan as a case study to improved.



36	37	31	44	38	36	30	36	34	42
30	30	30	30	30	30	30	30	41	30
30	30	30	30	30	30	30	30	30	30
30	30	30	30	30	30	30	30	30	30
30	30	30	30	30	30	30	30	30	30
30	30	30	30	30	30	30	30	30	30
30	30	30	30	30	30	30	30	30	30
30	30	30	30	30	30	30	30	30	30
30	30	30	30	30	30	30	30	30	30
30	30	30	30	30	30	30	30	30	30

Figure 18: Different routes cost for ten artificial ants for six cities

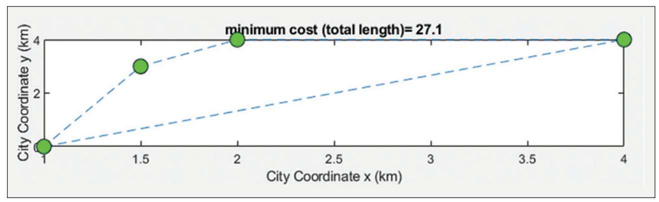
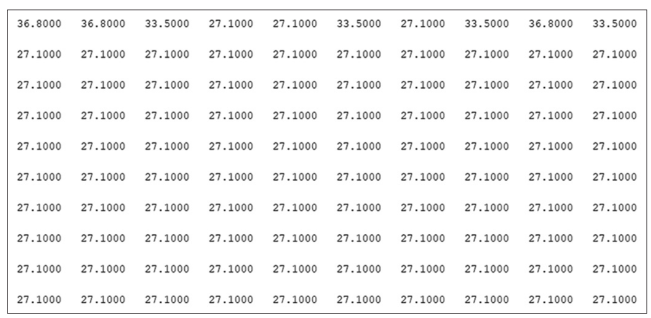


Figure 19: ACO Algorithm for multiple destination route planning for 4 cities



36.8000	36.8000	33.5000	27.1000	27.1000	33.5000	27.1000	33.5000	36.8000	33.5000
27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000
27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000
27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000
27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000
27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000
27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000
27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000
27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000
27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000	27.1000

Figure 20: Different routes cost for ten artificial ants for four cities

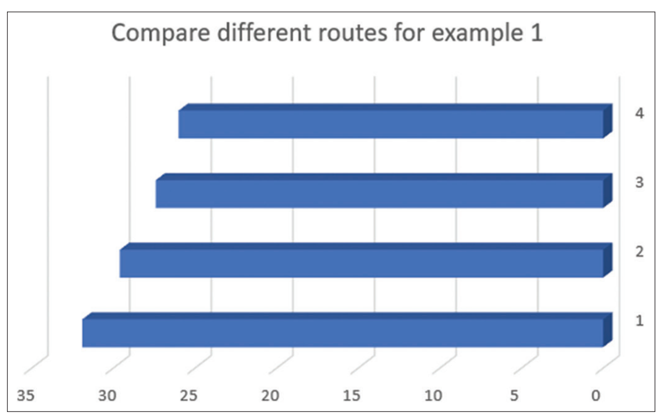


Figure 21: Compare ACO algorithm for multiple destination of cities in Erbil with Google map in example 1, where the minimum route is 26 km

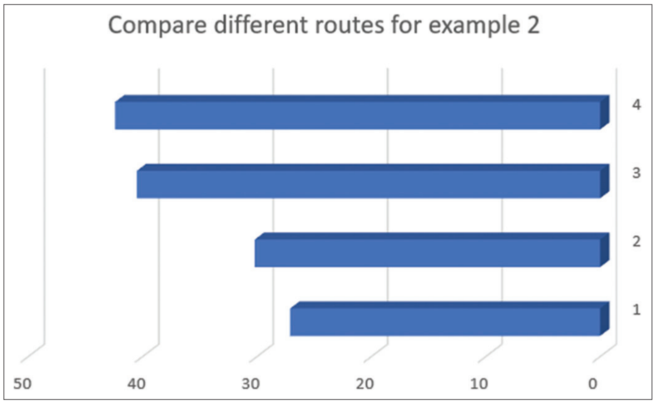


Figure 22: Compare ACO algorithm for multiple destination of cities in Erbil with Google map in example 2, where the minimum route is 27.1 km

CONCLUSION AND FUTURE WORK

This paper focuses on improving the routing algorithms in computer networks and in the real-life network when multiple destinations are needed. Most computer network routing algorithms that are configured for routers consider a single destination. In this paper, we have reviewed multiple destination route discovery protocols and analyze their challenges. Google Map is an application that has multiple destination service.

We identified the problem in Google Map Application when using the application with multiple destinations and proposed an improvement algorithm for multiple destination route discovery when using ACO algorithm. The *ACO Algorithm for Multiple destination route planning* gives the best route and the optimal cities sequence to visit. The results show a good performance when the shortest path is found and the new destination is added to the route plan.

For a future work, the proposed algorithm for multiple destination route discovery could be used in real-life services such as goods distributor driver and city bus scheduling for multi stop stations to develop many smart applications for the future of Erbil smart city.

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