# Modified Coral Reef Optimization Algorithm for Motorcycle Routing of Food Delivery Service in Thailand

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*Abstract*—**This paper investigates a case of a restaurant which provides the delivery of Thai barbecue (BBQ) food to customers around Nonthaburi Province, Thailand. Currently, the delivery planning is done by using personal experience which is inefficient. In order to solve this case study which was identified as a vehicle routing problem, with backhauls, a coral reef optimization algorithm is modified and compared to the real decisions of the planner who has motivated this problem. The results show that the proposed algorithm is competitive with the planner decision. The total delivery distances are also decreased by 17.97%. These results suggest that coral reef optimization algorithms may be useful to many different restaurant delivery services.**

*Index Terms*—**Vehicle routing, backhauls, transportation, coral-reef optimization algorithm.**

## I. Introduction

This paper focuses on a vehicle routing problem which is motivated by a real case study. The main activities as shown in Fig. 1 in this case study are purchasing food including pork, chicken, other meats, and vegetables entering into restaurant for the preparation of products as shown in Fig. 2. After that, restaurant handles the distribution of the products and electric stove burners loaded by motorcycle to customers located around Nonthaburi Province, Thailand.

Two groups of customers must be served. First group is the customers who order the products today, and need to receive products and electric stove burners loaded from the restaurant in order to cook themselves. Second group is the customers who ordered the products yesterday, and need to get used electric stove burners loaded back to the restaurant as shown in Fig. 3. Generally, both of the customer groups must be visited by only one motorcycle.

Fig. 4 shows a daily operation. In every evening, the restaurant receives the products from the kitchen and performs the routing by the only one planner who spends hours focusing on the route planning by using her own experience. After that, the products and electric stove burners are packed into baskets and delivered to the customers. When the delivery is done, the motorcycles will assign to pick up used electric stove burners from the customers, and will return to the restaurant.

The planning of each route must be performed within one hour. As mentioned earlier, the current route planning is not effective due to using personal experience of the planner. Therefore, the restaurant must improve the delivery efficiency in order to minimize the total delivery distances of the motorcycle routes by using a modified coral-reef optimization algorithm developed in this paper. It is a tool which will help the planner to assign the route of delivery to suitable motorcycles.

## II. Literature Review

The case study in this paper was identified as vehicle routing problem with backhauls (VRPB) that a motorcycle delivers products from restaurant to customers in linehaul, and picks up used electric stove burners from customers to restaurant in backhaul as shown in Fig. 5. The VRPB problem was first found in the publication of the article [1]. It is known to be an NP-hard problem [2-3]. The constraints of the VRPB are as follows.

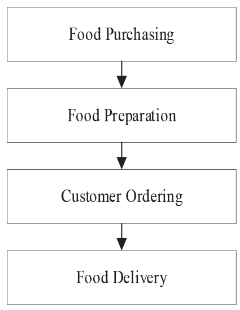


Fig. 1. Flowchart of main activities.

Fig. 2. Products.

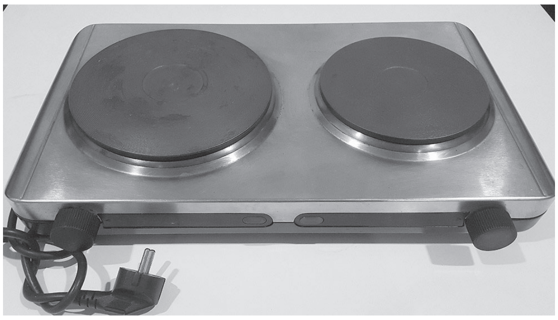

Fig. 3. Electric stove burner.

• Each customer is visited and left with the same motorcycle, and must be visited once by one motorcycle.

• Each motorcycle starts and ends at the restaurant.

• Each motorcycle contains at least one delivery customer (linehaul). Motorcycles servicing only pick-up customers (backhaul) are not allowed.

• All products and electric stove burners are loaded at the restaurant. All used electric stove burners are unloaded at the restaurant.

• The total delivery demand in each motorcycle (linehaul) cannot exceed the motorcycle capacity.

• The total pick-up demand in each motorcycle (backhaul) cannot exceed the motorcycle capacity.

• All motorcycles have the same capacity.

• Split demand is not permitted.

• The number of motorcycles used in each day cannot exceed the number of available motorcycles.

The study of the VRPB has attracted many researchers since the problem was proposed [2], [4-6]. Some well-known algorithms were proposed including exact algorithm [7-9], cluster-first route-second algorithm [10-11], Tabu search algorithm [12-13]. In this paper, we propose a modified coral reef optimization (CRO) algorithm [14] to solve the case study which scales well to real-world problem that are encountered in one of the food delivery business in Thailand. Moreover, the survey on literature reveals that there is no previously published research that presents CRO algorithm to solve the VRPB. This is our contribution to develop CRO algorithm introducing a new procedure which attempt to capture the nature of VRPB.

## III. Coral-Reef Optimization Algorithm

The coral-reef optimization (CRO) algorithm is one of optimization algorithms based on an artificial simulation of the mechanism of coral reefs' formation and reproduction. In order to solve the VRPB by using the CRO algorithm, we therefore modify the structures of the CRO algorithm that the flowchart is given in Fig. 6.

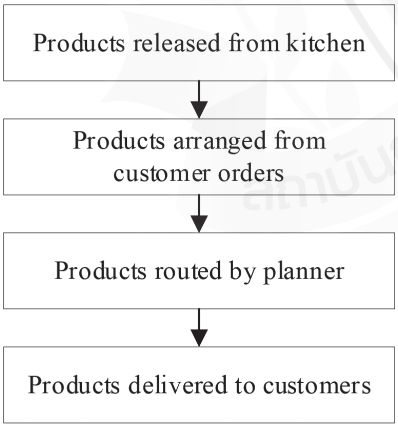


Fig. 4. Flowchart of daily operation.

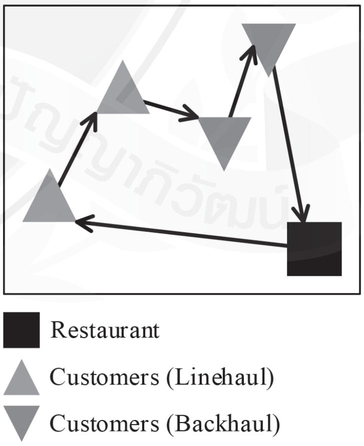


Fig. 5. Example of motorcycle route.

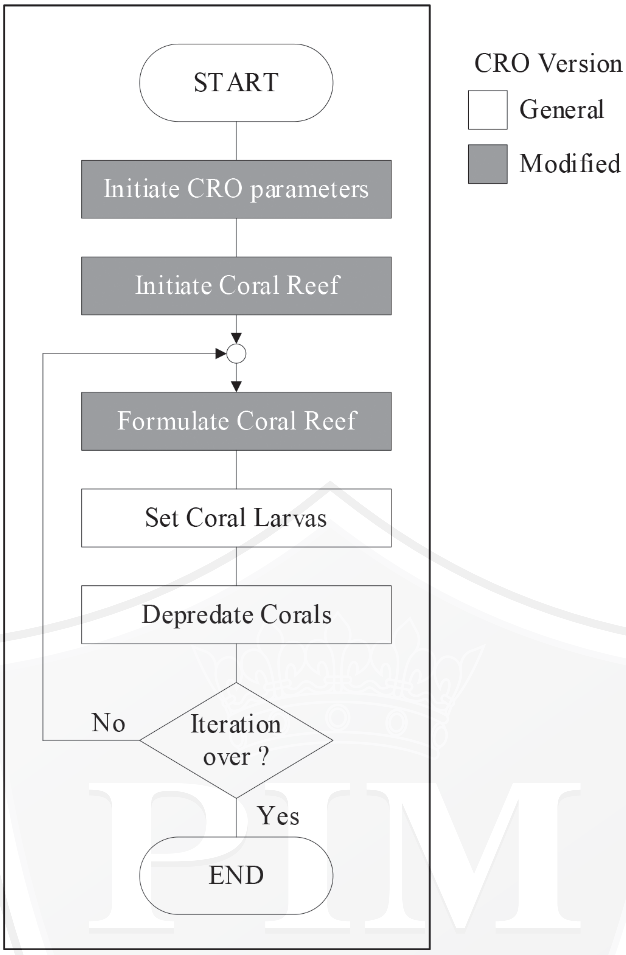


Fig. 6. Flowchart of modified CRO algorithm.

*A. Initiate CRO parameters*

The CRO algorithm includes some parameters which are described as follows:

• Coral reef is a set of corals consisting of a $N \times M$ square grid assuming that each square $(i, j)$ is able to allocate each coral.

• Coral represents a VRPB solution which is encoded as a string of the same nomenclature, consisting of a customer set identifier (including L = Linehaul, B = Backhaul) followed by *n* which represents the customer node number. For the customers in set L, they require delivery of products and electric stove burners from the restaurant. Set B is the customers who require pick up of used electric stove burners to the restaurant. The example of VRPB solution from coral encoding is shown in Fig. 7. It represents two routes as customer node. For the first motorcycle, it departs from the restaurant 0, delivers products and electric stove burners to customers L1 and L3, and picks up used electric stove burners from customers B1 and B2, and return to the same restaurant. For the second motorcycle, it departs from the restaurant 0, delivers products and electric stove burner to customers L2, and picks up used electric stove burner from customers B3, and return to the same restaurant.

• Coral larva represents the new solution produced by broadcast spawning procedure (when the egg and sperm from two corals meet together), brooding procedure (in case of self-fertilization in each coral), and budding or fragmentation procedure (when the coral has grown enough to produce budding or it is caused by storms and boats' grounding).

• Coral health represents the total delivery distances in each coral.

*B. Initiate Coral Reef*

In general, the CRO algorithm always randomly produces each coral to occupy in the reef. It assigns the corals to some squares in the grid and other squares to be empty which is represented by the holes in the reef where new corals can freely settle and grow in the future. In addition, we produce an extra coral by using the Clarke-Wright savings (CW) algorithm [15] in order to make a better chance to reach the best coral. After all corals are produced, the CRO algorithm will calculate the coral health of every coral. The example of a coral reef is shown in Fig. 8.

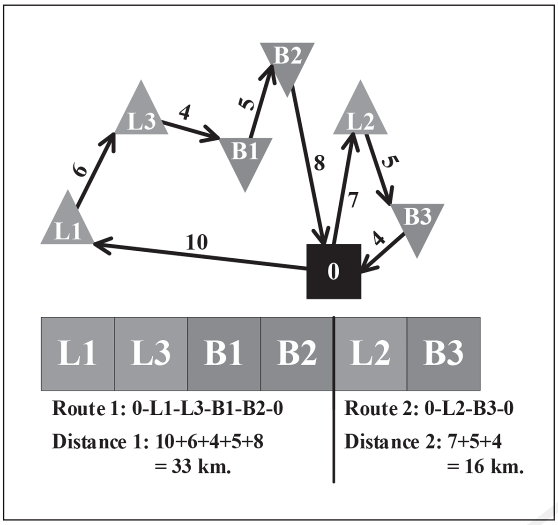


Fig. 7. Example of VRPB solution from coral encoding.

*C. Formulate Coral Reef*

A coral larva is produced by using broadcast spawning and brooding procedures which are described as follows:

*1) Broadcast spawning*

The existing corals in the reef are chosen at random to be broadcast spawners. Note that, the corals that are not chosen to be broadcast spawners will reproduce by brooding procedure. In the next step, couples out of the pool of broadcast spawner corals are randomly chosen. Each couple will form a coral larva by using inter-move operators [16] including shift moves and swap moves. The shift moves remove customers from the first coral and insert them in another place of the second coral. The swap moves select customers from both corals and exchange them. After that, the coral larva is released out to the water. Note that, the chosen corals are parents only once.

*2) Brooding*

As previously mentioned, each coral that is not chosen from the broadcast spawning procedure is reproduced to be a coral larva by using intra-move operators [16] including shift moves and swap moves. The shift moves remove customers from the chosen coral and insert them in another place of the same coral. The swap moves select customers from the chosen coral and exchange them. After that, the coral larva is released out to the water similar to the broadcast spawning procedure. After all coral larvas are produced, the CRO algorithm will calculate the coral health of every coral larva.

*3) Budding or fragmentation*

All corals are sorted by their health in ascending order. From these corals, the one is randomly chosen, and then duplicates itself to be the new coral larva. Set Coral Larvas

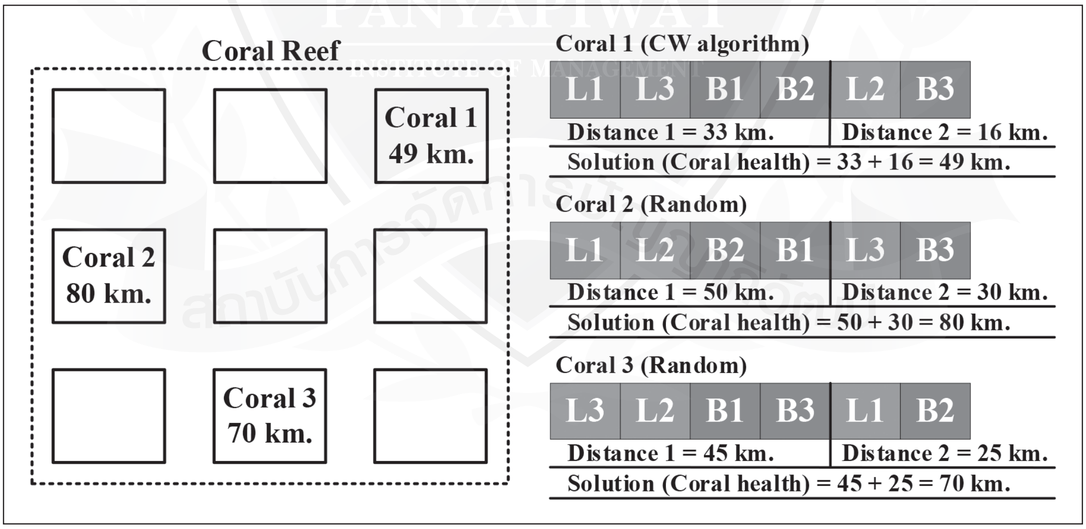


Fig. 8. Example of a coral reef.

*D. Set Coral Larvas*

When all coral larvas are formed through the procedures, they will try to set and grow in the coral reef one by one. First, each coral larva will randomly try to set in a square ($i$, $j$) of the coral reef. If the square is empty (hole in the coral reef), the chosen coral larva will grow to be the new coral in the coral reef. On the other hand, if this square is already occupied by a previous coral, the chosen coral larva will grow only if its health is better than the existing coral's health. Otherwise, it will be depredated by animals in the coral reef.

*E. Depredate Corals*

The corals may die when all squares in the coral reef are full in order to free space in the coral reef for next coral generation. The coral which has the worst health is chosen to be discarded from the coral reef.

*F. Stopping Condition*

The process of the CRO algorithm is continued until the stopping condition represented by the number of iterations is satisfied. It will stop and select the best coral in terms of total delivery distances as the final solution of the VRPB.

## IV. Computational Results

The proposed algorithm was coded in Visual BASIC 6.0 on an Intel® Core™ i7-5500U CPU 2.40 GHz with 8.00 GB of RAM under Windows 7 64-bit platform. For CRO algorithm, we have set the coral reef to be 3 × 3 square grid and the total number of iterations equal to 1000.

The real-world problem from the restaurant in Nonthaburi Province, Thailand was tested. The numerical experiment used real data provided by the restaurant. In this experiment, the case study depends on three days of delivery in September, 2019. Each day is separated by considering a number of customers (including low, medium, high).

We discuss the case study that the percentage deviation between the solutions obtained from the proposed algorithm ($cro$) and the planner's experience (exp) is calculated as follows:

$$\text{Percentage deviation} = \left(\frac{cro - \exp}{\exp}\right) \times 100 \qquad (1)$$

From the results in Table I, we found the new solutions for all days. The total delivery distances are decreased by 17.97%. It can be shown that the motorcycle route planning obtained by the proposed algorithm is better than the planner's experience in all directions. Moreover, we provide the example of motorcycle route planning in day 1 by the planner's experience and the proposed algorithm which are illustrated in Figs. 11 and 14. Figs. 9 and 12 show the delivery routes in linehaul, and Figs. 10 and 13 show the pick-up routes in backhaul by the planner's experience and the proposed algorithm.

## V. Conclusion

In this paper, we have presented a modified coral-reef optimization algorithm to solve the vehicle routing problem with backhauls and the real-world problem which concerns with the route planning of the motorcycles to deliver the products and electric stove burners from the restaurant to the customers, and pick up used electric stove burners to the restaurant. The numerical experiment has been done by using the real data provided by the restaurant comparing with the planner's experience. From the numerical test, the proposed algorithm is competitive in terms of the quality of the solutions found, and shows better performance for the real-world problem. It is shown that the proposed algorithm can be used to solve this kind of problem.

TABLE I

Computational Results

| Day | Number of customers | Number of motorcycle routes | Solution (km.) | |
|---|---|---|---|---|
| | | | Planner's experience | Proposed algorithm |
| 1 | 21 | 2 | 52.36 | 41.37 |
| 2 | 32 | 2 | 87.22 | 76.81 |
| 3 | 50 | 3 | 80.26 | 62.15 |

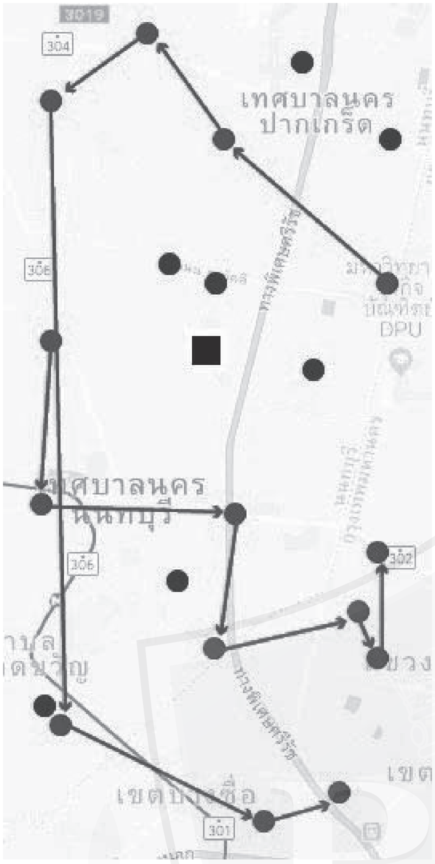


Fig. 9. Delivery route (linehaul) by planner's experience.


Fig. 10. Pick-up route (backhaul) by planner's experience.

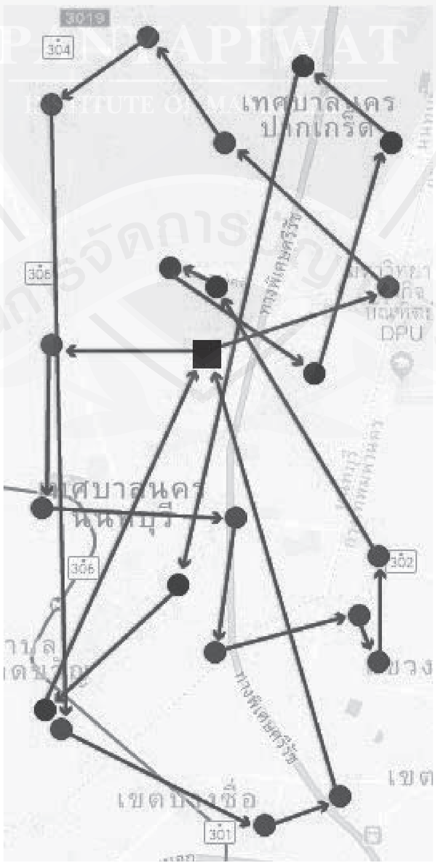


Fig. 11. Motorcycle route by planner's experience.

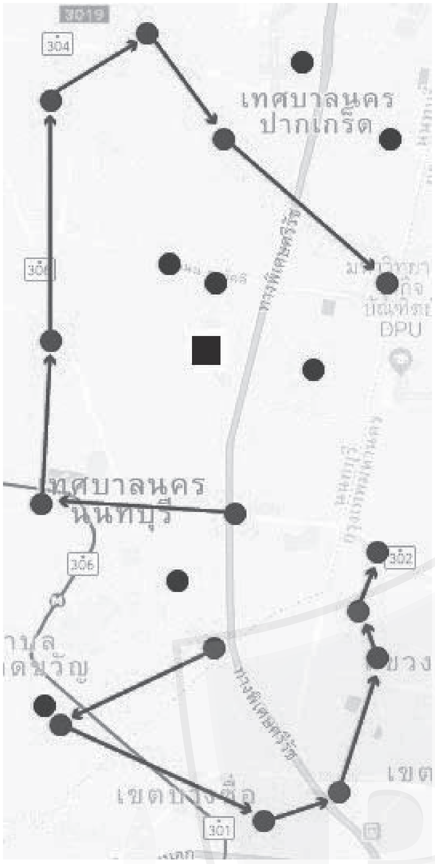


Fig. 12. Delivery route (linehaul) by proposed algorithm.

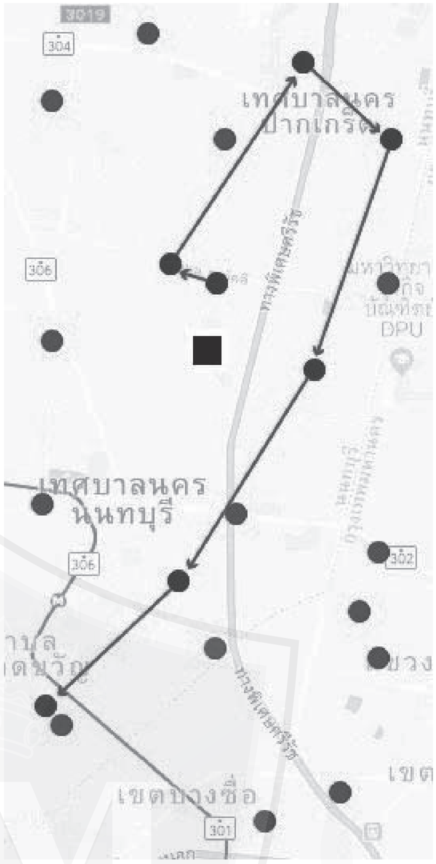


Fig. 13. Pick-up route (backhaul) by proposed algorithm.

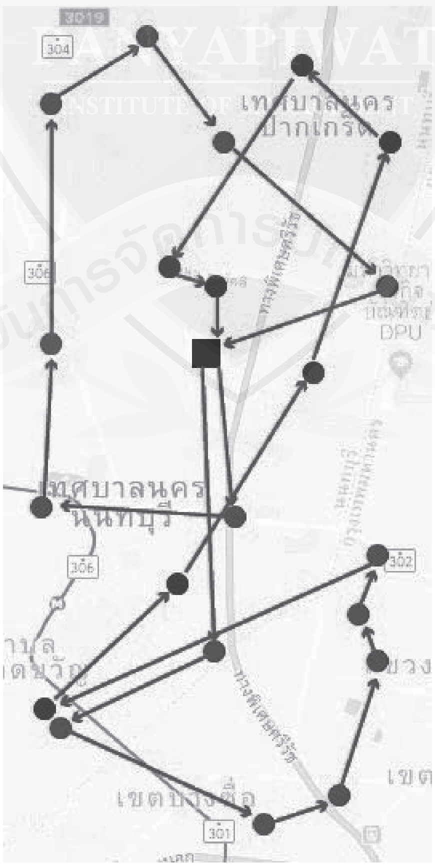


Fig. 14. Motorcycle route by proposed algorithm.

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