Solving a Multi-Objective, Source & Stage Location-Allocation Problem Using Differential Evolution

Rapeepan Pitakaso
Department of Industrial Engineering, Faculty of Engineering
Ubon Ratchathani University, Ubon Ratchathani, Thailand
Tel: (+66) 85-921-0826
Email: enrapepi@mail2.ubu.ac.th

Thongpoon Thongdee†
Department of Industrial Engineering, Faculty of Engineering
Ubon Ratchathani University, Ubon Ratchathani, Thailand
Tel: (+66) 84-099-9926
Email: thongpoonthongdee@gmail.com

Abstract. The objective of this research is to select some potential sites to be opened as the ethanol plants. The selected plants will use bagasse from sugar industries and cassava pulp from cassava flour industries as the raw material of their production process. The case study will scope in northeastern area of Thailand. The objectives function that we consider including economic, environmental and social risk objectives. The case study addressed above is the multi-stages multi-objectives location allocation problem because of after the selection of the ethanol plants, then the open ethanol plants need to make decision to deliver ethanol to the blending centers which also select from the potential site of blending center to make gasohol. The process of solving the case study is as following: firstly, we formulate the mathematical model to represent the case study and then solve it by optimization software package (Lingo v.11). Lingo v.11 can find optimal solution but use more than 30 hours computational time. Currently in this article, we develop differential evolutionary algorithm (DE) to solve the case study. From the computational result DE can find 1.8% higher cost than that of Lingo but use 98% less computational time.

Keywords: Location allocation problem, Meta-heuristics, Differential Evolution, Multi-objective optimization, Ethanol plant.

1. INTRODUCTION

The phenomenon of global warming are clearly reflected in the present. This brings many countries issue the defensive measure to prevent environmental destruction. Thailand has focused on promoting the use of renewable energy such as bio-fuels, wind power, solar power. As well as strategies to promote the use of alternative fuel, gasohol instead of the gasoline 95 which is the government provides and support for production, advertising and Public relations. From the current situation of crude oil price and the oil continued to move higher, resulting in Thailand on the need of rely on imports, this is cause to loss the money out of country to imports large amount of fuel. In the future, world oil price will likely increase the need to find new sources of renewable energy. Which is popular now is "ethanol".

From the Department of Energy's information in January 2010 showed that in north-east of Thailand, the plant is allowed to operate up to 16 plants of 24 plants that are allowed in the country. If only considering the used material to produce ethanol today will find that all plants

†: Corresponding Author
will selection two types are Cassava pulp and Tapioca. Both raw materials are important and there is the high demand in other industries as well. So to prevent the impact of shortage this will come sooner, this research was conducted under the economic objectives, impact on the environment and safety risk.

This research has studied on location selecting two-level. By define the raw material sources to produce ethanol from two places including the two-level transportation routing selection. Further that this research is also framing the problem as a multi-purpose to reflect and optimize decision making. And to define the development policies with the plan for sustainable energy next step. Although renewable energy or ethanol is crucial, but to establish the plant to produce ethanol would need to study and focus on all factors that affect the production. Minnesota Pollution Control Agency (2007) has been studied and identified the important factors in choosing a location of ethanol plant, which include water source used in the manufacturing, the waste water treatment from the manufacturing, the readiness availability of raw material, the transportation of raw material and ethanol, the type of fuel used in production, funding and the policies of the government and the impact of production processes that affect people in the area.

Buddadee et al. (2008 and 2009) studied the selection location of ethanol plant using bagasse by studying the economic value and the environment impact. Resulting that using bagasse has the economic value and reduce environmental impact in term of reducing greenhouse gas emissions into the atmosphere as well as Nathahasamroeng et al. (2008) has studies the selection location of ethanol plant with the multi-objectives by the problem defining on selection of ethanol plant location will have specific four characteristics. 1) The fix customer location 2) The plant location to locate itself 3) The location of customer and factory 4) distance between customer plants, Jozefowiez et al. (2008) In additions, the study is a two-level location selection which is the two-level transport vehicle routing (two-level location routing problem).

For this research, studies in the same problem with Nathapong but extend the form of problem to additional the material sources (Multi-source). This is considering the raw material source to produce ethanol as bagasse and cassava pulp. And increase the satisfaction of the society surrounding community from the producing ethanol plant community. If the transportation of ethanol has ethanol leakage, this is considered dangerous because the ability to ignite. The above problem can be solved with software package LINGO Version 11.0. However, the experiment with LINGO version 11.0 is limited on the increasing the size of numerous material sources and the potential point to establish ethanol plants. This is because the software backup memory is not enough to the complexity of the problem is increasing. This research need to be solved will be develop DE to solve that for case study.

2. LITERATURE REVIEWS

Lin and Kwok (2006) applied two other classes of meta-heuristics: Tabu Search (TS) and Simulated Annealing (SA), and compared their performances through a new statistical procedure. Drezner et al. (2006) is another example in which they have use two heuristics including Tabu Search and a decent algorithm for their minimax regret multi-objective problem. Stummer et al. (2004) extended the original Tabu Search algorithm and implemented a multi-objective version with a population set, in the first phase of their algorithm, following by a k-means clustering in the second phase to allow the decision makers to interactively explore the solution space to determine the “best” configuration. Caballero et al. (2007) used the multi-objective meta-heuristic using an adaptive memory procedure (MOAMP) method, which is based on Tabu Search. Uno and Katagiri (2008) proposed to apply the interactive fuzzy satisfying method with a Tabu Search algorithm in order to find several M-Pareto optimal solutions in their location problem, which they regarded as a multi-objective two person zerosum Stackelberg equilibrium game.

Raisanen and Whitaker (2005) implemented a greedy algorithm whose performance was dependent on the order in which the candidate sites are considered. In order to find an optimal ordering of potential base stations, four multiple objective Genetic Algorithms, Simple Evolutionary Algorithm for Multi-Objective Optimization (SEAMO), Strength Pareto Evolutionary Algorithm version 2 (SPEA2), Pareto Envelop based Selection Algorithm (PESA) and Non-dominated Sorting Genetic Algorithm II (NSGA-II), were compared from many different terms, such as simplicity, quality of solution, time, etc. Cantarella and Vitetta (2006) to deal with large scale versions of their problem, they proposed a multi-level heuristic algorithm. At its outer level, new network configurations were analyzed by a Genetic Algorithm and at its inner level, the traffic signal setting and flow assignment were performed within an asymmetric user equilibrium assignment. Finally, the solutions were tested through some approaches including a clustering procedure, and calculating the values of criteria.

Doerner et al. (2007) proposed three algorithms: Pareto-ant colony optimization (P-ACO) technique and performed a selection of tour stops and tour constructions simultaneously, Vector Evaluated Genetic Algorithm (VEGA) and the Multi-Objective Genetic Algorithm (MOGA) and performed the selection of tour stops on an
upper procedure level and tour construction in a 2-opt sub-local search. In the end, they suggested a combination of Pareto-ACO and MOGA as a promising technique to find an adequate set of good solution candidates. Zhang and Armstrong (2008) is another example in which Multi-Objective Genetic Algorithm (MOGA) was applied to their problem. Leung (2007) proposed a Genetic Algorithm for its combinatorial goal programming model. The author finds this method more flexible and effective than common models such as the standard gravity model or entropy-maximization model.

Carrano et al. (2007) for the bi-objective joint facility location and network design problems (MJFLND), a two-modularized algorithm was used in which a multi-objective quasi-Newton algorithm was responsible for finding the location of the facilities; and a multi-objective Genetic Algorithm, was used to find the efficient network design. Moreover, a heuristics was applied to switch between these modules in order to find an efficient solution.

Dias et al. (2008) an interactive Memetic Algorithm integrating genetic procedures and local search was proposed. The interaction with the decision maker is to define interesting search areas by establishing upper bounds to the objective function values, or through the indication of reference points. It seems that reference point approach built more and better solutions in less iteration.

Medaglia et al. (2009) is another example of application of Non-dominated Sorting Genetic Algorithm II (NSGA-II) in multi-objective facility location problems. They combined their algorithm a fast greedy fitness assignment heuristic (GA-GAH), and with a fitness assignment approach based on mixed integer programming (GA-MIP) for its fitness function. Experiments showed that the hybrid GA-MIP obtained better solutions, based on the size of space covered (SSC) metric. Moreover, GA-MIP was compared to the non-inferior Set estimation (NISE) method, and from different points of view, GA-MIP showed a better performance than NISE.

Xu et al. (2008) proposed an approach of spanning tree-based Genetic Algorithm (st-GA) by the Prufers number representation to solve the problem. They also utilized the expected value and chance-constrained operators, to deal with the random fuzzy objection functions and the random fuzzy constraints and turning them into a deterministic model.

Doerner et al. (2009) utilized a non-dominated sorting Genetic Algorithm II (NSGA-II) approach and compared it with a decomposition technique where decomposed problems were solved either exactly or heuristically. Results showed that when it comes to the size of a problem, this algorithm is efficient in time and quality.

3. RESEARCH METHODS

This research is divided into three phases are preparation phase, the design of mathematical models phase and the after operation phase.

Firstly, literature reviews in matters relating to solve the selection of routing and location (Location routing problem) multi-stages, multi-source and multi-objective. Secondly, define the status of problem by determining the mathematical model into the form integer linear programming as shown in figure 1 which aims to find the location of ethanol plant consist of minimal operation cost, minimal environment effect, minimal safety risk and maximal satisfaction of surrounding society and community.

Thirdly, collect information to be used in research case studies of ethanol production from bagasse and cassava pulp is in the north-eastern. Fourthly, operation and preprocessing the data were gathered all from the DE solving.

Then, summary and discuss the results.

Figure 1: The supply chain of the Ethanol production for mixing to produce the gasohol

3.1 Mathematical models for selecting the plant location

All mathematical models for this research refers the study of Thongdee and Pitakaso (2012)

3.2 A case study of a bagasse and cassava pulp ethanol plant in northeastern Thailand

The 16 sugar plants and 46 starch plants in the north-eastern have been defined as a source of raw material that are distributed in different provinces as shown in figure 2. But for this study was to prove a mathematical model is corrected and the up the speed of computer processor. Therefore, selection the sugar and starch plants each 5 plants. With the criteria on location of the plants by rating, and choose the plants that has score in the top 5, as shown in table 1 and 2.
This paper will be selected by an ethanol plant at an existing site in the north-eastern area of the actual production. Additional the developing and manufacturing technology to produce the bagasse and cassava pulp to produce ethanol with still remaining the current production capacity. In which the detail of all data for this research refers the study of Thongdee and Pitakaso (2012). When collection data completion, all information will be used in the processing of DE development and to be solving.

The selection of location and the vehicle allocation in the case study ethanol plant in north-eastern area of Thailand is the solving problem for the three objectives. (1) Economic objectives, the cost reduction on transportation and plant construction, (2) Environmental objectives, the reduction of greenhouse gas emissions from all processes of production and transportation and, (3) the risk to safety. This minimizes the risk that could happen to people who live in the transportation area if the leakage happened.

### 3.3 Research resulting by DE

Thongdee and Pitakaso (2012) was tested the same problem but tested by software package LINGO 11.0 has limited with the time constraint. Each case must be at least 30 hours. And if we need a large number of sugars and starch plants additional data input, the test will take a huge time to run trial or might be not even able to use the LINGO. In the purpose to have more performance on testing, the test shall use higher level if testing. That is the heuristic and meta-heuristic method, the form of algorithm design to be trial in the future, therefore was DE development and solved that problem and comparison the performance with LINGO 11.0.

#### 3.3.1 Algorithm development using differential evaluation

The researcher design and develop the algorithm into two parts 1) the beginning solution seeking algorithm by selection the position to open the plant and allocation the route to transport raw material and ethanol product 2) the improvement beginning solution algorithm

The algorithm development process and the calculation to allocation the ethanol plant which using raw material from bagasse and cassava pulp. This is the lowest processing cost, lowest effect to environment, lowest risk to safety and highest social satisfaction. The researcher introduce meta-heuristic method to calculate the allocation which can show as the procedure in flow chart as in figure 4 and show the Pseudo-code to write program C++ which is can solving the problem faster, this is on figure 3.

#### 3.3.2 Beginning solution seeking

The researcher applies the beginning solution seeking procedure inspired from the Genetic Algorithm (GA). Assign the quantity of chromosome particle equal to the number of existing capable ethanol plant and able to addition investment for received more raw material to produce ethanol. The crossing particle in chromosome will be the parts of sugar plant, cassava flour plant and tank farm which are the horizontal cell and the ethanol plant in vertical cell.

---

**Figure 2: Location of Sugar plants, Starch plants, Ethanol plant and the Gasohol mixing plant in North-eastern**

**Figure 3: Pseudo code for the DE algorithm**
To find the beginning solution of algorithm, after assign beginning chromosome starting with random number from 0.0 – 1.0 for each array in the chromosome by pass the procedure reference RBS rule. Starting from create array with column M1 = 5 and crossing with M2 = 66, then random number from 0.0 – 1.00 into each array. When get the value of each array, start compare the value. The highest value in each column (M2) is selected to operating or transfer each other which is the decision to open the ethanol plant or not.

3.3.3 The improvement of solution by differential evolution

The researcher select the differential evolution, because of this is the challenge and inspire from the literature review about the meta-heuristics method development as table 1. The researcher selects the algorithm development with differential evolution to solve this problem because of the characteristic of this problem has rarely found other researcher applying. Also this is not complicated algorithm and give the acceptable solution from relate literature review. The procedure of this algorithm is started from create the beginning solution which is use the RBS algorithm as previous subject. Then start into the solution improvement process from mutation and then get in the crossover genetic process, and finally the selection process.

Table 1: Summarize of literature review for the meta-heuristic about multi-objective and location-allocation

<table>
<thead>
<tr>
<th>Problem (MOSS-LAP)</th>
<th>DE</th>
<th>GA</th>
<th>TS</th>
<th>PSO</th>
<th>ACO</th>
<th>SA</th>
<th>ILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-objective</td>
<td>13</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Multi-stage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location-allocation</td>
<td>17</td>
<td>6</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Score</td>
<td>0</td>
<td>30</td>
<td>12</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Remark: Differential evolution (DE)
Genetic algorithm (GA)
Tabu search (TS)
Particle swarm optimization (PSO)
Ant Colony Optimisation (ACO)
Simulated Annealing (SA)
Iterated Local Search (ILS)

Figure 4: Development Flow Chart for DE algorithm
3.3.3.1 The Mutation Process

Start the mutation by collecting target vectors to produce the mutation vector in each target vector index $i$ as $X_{i,g}$ which is the $g$ generation. For the mutation vector is $V_{i,g}$ by create from this model

$$V_{i,j} = X_{r1,g} + F(X_{r2,g} - X_{r3,g})$$

There is the notice that $X_{r1}, X_{r2}, X_{r3}$ have random from the vector population which is different from target vector $X_{i,g}$. For $F$ is the level of factor that controlled the vector differential between $X_{r2}, X_{r3}$ then add into the standard vector is $X_{r1}$

3.3.3.2 The Crossover Genetic process

This is the evolution from crossover between $X_{i,g}$ and $V_{i,g}$ for the testing vector; $U_{i,g}$ which is derived from beginning solution chromosome set and the mutation solution chromosome. The rule os randomize number from 0 to 1 for the beginning chromosome in crossover process that will call later as Trial vector

3.3.3.3 Selection

TheSelection is the solution selection process which is the better solution vector will be alive. The selection process assign each vector as $X_{i,g}$ and the conforming testing vector is $U_{i,g}$. This is using for comparison testing the solution of target equation with the survival to be the next generation. The vector $X_{i,g+1}$ will be selected as the criteria as following

$$x_{i,j} = \begin{cases} u_{j,i,g}, & \text{if } u_j \leq c, \text{ or } j = j_u \\ x_{j,i,g}, & \text{otherwise} \end{cases}$$

When $C_r$ (Crossover Rate) is the constant $[0,1]$

$$i = 1,2,\ldots,N; \quad j = 1,2,\ldots,D$$

The question (2) explain that when random value in each array in the chromosome which are the number from 0 to 1, if the value is less than or equal $C_r$ (Crossover Rate) then select the value from mutant vector. If others, then select the target vector.

3.4 The algorithm testing result

The researcher test algorithm by design the testing and found that the solution has decreasing function value. This is according to the objective research that would like to find the minimize value. The calculation result and the performance test of algorithm by differential evolution can show in table 2 and the comparison of performance between LINGO 11.0 with DE algorithm can show as table 3 as below.

![Table 2: The calculation result and the performance test of DE algorithm](image)

![Table 3: The comparison of performance between LINGO 11.0 program with DE algorithm](image)
As table 3 there can show that the solving method between Lingo 11.0 and the DE has obvious different. The function value of Lingo method is a bit better than DE method about 1.8%. Anyway the time to solve the problem have a big different, the DE consume the solving time about 0.12% of total Lingo solving time. The alternative of solving method might depend on how much time for any project has to running is. Normally the shorter time method with not significant different on value will be chosen.

4. SUMMARY

The test results by DE showed as table 2, the K.I. Ethanol Co.,Ltd., (Nakorn Ratchasima) will received only cassava pulp to produce ethanol. The Petro Green Co.,Ltd. (Kalasin) will received both bagasse and cassava pulp to produce ethanol showed detail in figure 5.

The testing result derived from DE development to solving multi objective, source and stage location was found that the developed DE can solve this problem well. The comparison of calculation between objective value and the program solving is not significant different which only 2 percents is. Beside that, the DE solving method 98.8% is faster than using the program solving. Also the limit of program solving is a big size of problem. But the DE development can solve more complexity or bigger problem than this. The developed DE is also suitable for the complexity sequential allocation. Then this can be summary that the developed DE is able to solving the studies problem well. This summary is reference from the comparison with LINGO 11.0 result, Thongdee and Pitakaso (2012) which is not significantly different.

ACKNOWLEDGMENT

Ubon Ratchathani University research team, thanks for the knowledge of how to do research. And thank the Fund for the promotion of energy conservation, Department of Energy for the funding of this research

REFERENCES


**AUTHOR BIOGRAPHIES**

**Thongpoon Thongdee** is a Ph.D student in Department of Industrial Engineering, Faculty of Engineering, Ubon Ratchathani University, Ubon Ratchathani, Thailand. He received a M.Eng (Engineering Management) from Industrial Engineering at Kasetsart University in 2008. His research interests include operation management, applied operations research and simulation in production and operation management. His area of specialization is Lean Simulation and TQM. His email address is thongpoonthongdee@gmail.com

**Rapeepan Pitakaso** is a lecturer in Department of Industrial Engineering, Faculty of Engineering, Ubon Ratchathani University, Ubon Ratchathani, Thailand. He received a Dr.rer.soc.oec. His research interests include operation management, applied operations research and simulation in production and operation management. His area of specialization is Meta-heuristics. His email address is <enrapepi@mail2.ubu.ac.th>