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Original Article

Application of *Modified Differential Evolution* for the supply chain management of rice in the lower North-Eastern Region of Thailand

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Abstract

This research presents the application of *Modified Differential Evolution* (MODDE) for the the supply chain management of rice in the Lower North-Eastern region of Thailand in order to compare the efficiency of the problem solution with the *Differential Evolution* (DE) Method and also to reduce logistical costs in the Lower North-Eastern region of Thailand by experimenting with real and randomly generated problems with a total of 17 instances. 14 instances are of small and medium size problems. Computational results show that MODDE can produce in average 92.38% of *Global Optimal*; answers obtained from Global Optimal are about 0.0448% different and the average computing time is about 2.27% shorter than for DE. If the problem is larger, it is found that MODDE can encounter a *Best* solution difference from the best objective of -3.5838% in average. It can also reduce the objective value of the case study (I93-J12-L18-N12) by 10.64%.

Keywords: the supply chain management of rice, modified differential evolution (MODDE)

1. Introduction

At present, Thailand's logistical costs are relatively high, at an estimated 1835.2 billion Baht, which is the equivalent to 14.2% of the country's gross domestic product (GDP). The main costs, which include the transportation costs of goods amount to 953.2 billion Baht, accounting for 7.4% of the GDP, and storage costs of inventory, valued at 715.2 billion Baht and accounting for 5.5% of the GDP (Office of the National Economics and Social Development Board [NESDB], 2014). This has resulted in various industrial sectors having to bear this cost, thereby reducing Thailand's competitive capability as a major rice exporter of the world. In 2014, Thailand exported 10,969,361 tons of rice, which accounted for 37% of agricultural products exported from the country with an export value of 174,854.73 million Baht and accounting for 25% of these agricultural products (Office of Permanent Secretary, Ministry of Commerce [OPS], 2014) were 13,130,284 tons of rice paddies, 36% of which came from the North-Eastern Region of Thailand (Office of Agricultural Economics [OAE], 2014). When the production capacity of the rice mills was analyzed according to the Ministry of Industry criteria, it was found that 66.2% of rice mills are located in the North-Eastern region and 62% in the lower North-Eastern region of Thailand (Department of Industrial Works [DIW], 2014). 6,969,632 tons or 53.08% of the total rice paddy yield of the North-Eastern region comes specifically from four provinces in the lower North-Eastern region of Thailand, namely Ubon Ratchathani, Surin, RoiEt, and Nakhon Ratchasima. These provinces generally yield more than one million tons per crop each year (OAE, 2014).

The performance of the supply chain management of rice in the lower North-Eastern region is measured by Thoucharee and Pitakaso (2012a). The model has been developed to measure the performance by taking the *Supply Chain Operation Reference Model* (SCOR Model) and logistics cost analysis using the *Activity-Based Costing* (ABC) method. It is found that the highest costs can be attributed to

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transportation and storage costs of inventory in the warehouse of the stakeholders. Therefore *Value Stream Mapping* (VSM) is applied for designing the supply chain of rice (Thoucharee & Pitakaso, 2012b). The supply chain of rice is designed as shown in Figure 1.

For the rice supply chain as shown in Figure 1, Thoucharee *et al.* (2013) created a mathematical model that focuses on the integration of inventory and transportation, because it is the highest value cost, from farmers to rice mills and from rice mills to exporters and wholesale dealers. The mathematical model consists of three objectives. (1) Cost is a measurement of the cost of logistics activities in the logistics system and rice supply chain by activity-based costing (ABC), (2) Opportunity is an opportunity cost to sell rice at a high price, and (3) Time is the time spent on each logistics activity in the supply chain of rice. When the application using differential evolution (DE) for comparing the performance solutions with Lingo V.11 program, it was found that when the scope of the problem increases the differential evolution (DE) cannot find an appropriate solution. Thus, this research aims to apply the *Modified Differential Evolution* (MODDE) with logistics and supply chain management for rice of the lower North-Eastern region of Thailand for comparing the performance solutions with *Differential Evolution* (DE) in order to reduce logistical costs of the lower North-Eastern region of Thailand.

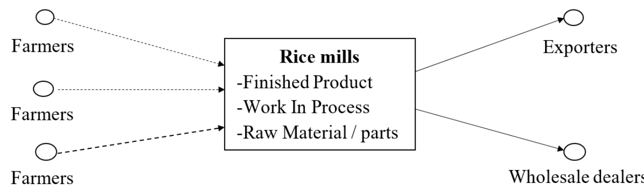

Figure 1. Supply chain of rice designed by *Value Stream Mapping* (VSM).

2. Literature Review

A literature review will focus on developing methods of heuristics to raise the efficiency of mathematical models as shown in Section 2.1.

2.1 Heuristic method

When a problem gets larger, the number of feasible solutions within the scope of the problem increases making the time of finding the answer (solution) longer as well. Methods for finding the solution are divided into two main groups: 1) the heuristic and 2) the *Best Answer* or *Exact Method*, well-known examples of which are the Simplex Method, Branch and Bound, etc. The heuristic method is a method to find the best answer in an appropriate time period. The answer obtained from the heuristic method cannot guarantee that it is the optimal solution to that problem; it is a good answer and one which is provided within the appropriate time period. Generally, a heuristic approach is designed to solve problems with different characteristics, so the heuristic method has no exact form and can be adjusted according to the characteristics of that particular problem (Pitakaso, 2011). Gabor and Said (1996) presented heuristic approaches to solve the problem of size limitation. The heuristic method was applied to estimate customers divided into groups called "cluster-based" in the allocation of customers at the distribution center. The next stage was to create routing by Clarke and Wright saving heuristic method. Three years later, Tuzun and Burke (1999) presented a two-phase Tabu Search to solve the problem of choosing the location and managing transportation routes with the problem size of 200 customers by comparing the answers and spending time with the Saving heuristics method. The results showed that answers from the designed Tabu Search were better than those provided by the Saving Method however they did require more computing time. Blum and Roli (2003) said that the primary principles of meta-heuristics were as follows: 1) The Meta Heuristic approach is used to find the best answers within a set of possible answers; 2) Meta-Heuristics objective is to find the best closest answer to real answers within a reasonable time period; 3) Meta-Heuristic employs both complicating and uncomplicating methods and systems such as Local Search, Ant System, Genetic Algorithms, Tabu Search, and Simulated Annealing etc.; 4) Meta-Heuristic might be formed by a combination of various methods to find the best answers within possible answers; 5) Meta-Heuristic utilizes orderly procedures but adjusts details when applied to individual problems; and 6) some Meta-Heuristic modes such as the Tabu Search Method and Ant system have more temporary memories in recognition of the original answers.

Differential evolution (DE) was one of the algorithm evolutions (EAs) used to enhance efficiency in searching for the global solution continuously (Storn & Price, 1997). Its theory frame was a simple model and used less CPU time (Bin *et al.*, 2008). Although it had a relatively low relationship of the control variables it worked efficiently. The evolution was widely applied and showed strength points in many applied areas (Qian & Li, 2008). Dervis and Selcuk (2004) explained that Differential Evolution Algorithms (DEA) was a form of Evolutionary Algorithms (EA), involving one procedure of Differential Evolution, being new techniques of increasing efficiency with the ability to manage problems to be non-differentiable, non-linear and multimodal objective functions. Thus, the DE had to increase the working time for larger sized complex problems in order to enhance the efficiency in searching for objective functions. In his simulation study, De Jong found that the speed of convergence of DE was significantly better than the Genetics Algorithm (GA). Hence, DE algorithm seemed to be the most efficient method to solve problems and it also enhanced the engineering efficiency. Liu and Lampinen (2005) had improved DE by adjusting Fuzzy Adaptive Differential Evolution Algorithm (FADE), adjusting the Weighing factor (F) and Crossover rate (CR). This method would adjust the mutation control variables and Crossover control parameters. The usage of fuzzy logic control methods of FADE parameters of the response to the population information was vector parameter functions, making DE to find answers quicker. New adjusted F and CR could give better answers than conventional DE. Qin and Suganthan (2005) used a method called SADE to improve F and CR control factors. It needed not be predetermined during the evolution parameters that would gradually adjust itself according to the learning experience. The efficiency of the heuristic method called Safe Adaptive Differential Evolution (SADE) has reported on a series of 25 standard functions in case of CEC2005 using real parameters. Chakraborty *et al.* (2006) presented a new mutation of DE method by finding two types of simulations of DE to test the mutation of three factors. This presentation showed significantly better answers than the three factors. The popular breeds in DE by using six testing functions for searching efficient measures were the quality solution, time of solving problem frequency of solutions and the size of the solution. Kaelo and Ali (2006) used a number of problem sets of 50 in testing of DE mutation both old methods and developed a new one. The new method could provide good answers of 20 problem sets from previous comparison. It is quite assure that the procedures of new method are better than that of traditional DE method.

It is therefore clear that Differential Evolution (DE) is the best method to apply to this research, because it is the methodology for finding appropriate values of stochastic and random base Global Search Space, which randomly operates to find a covering answer. The idea of genetic hypothesis is the same as GAs but has distinctive advantages such as having less structure of complex methodology and more globalizations. Farther more, it can also use floating point real numbers in calculation without the need for converting the decision variables to binary numbers. That is a major reason, why DE is a faster and more efficient method for finding the answers than other methods and when Improve or *Modified Differential Evolution* (MODDE) also can give better answer. Consequently, this research will apply *Modified Differential Evolution* (MODDE) to solve the problem of the rice supply chain in order to compare the efficiency with that of the Differential Evolution (DE) and to reduce the logistical costs in the lower North-Eastern region of Thailand.

This manuscript includes details of the methodology of heuristics presented in section 3. The experimental framework and the computational results are presented in section 4 and section 5 is the conclusion of the article.

3. Methodology

Modified Differential Evolution (MODDE) is made up of 4 main steps as follows: 1) Initialization: this is the sampling of the initial population under constraints. 2) Mutation: this is gene transformation in order to get the new answers distinct from population groups in 1). 3) Crossover: this is the blending of breeds into various new breeds of better or worse answers to find breeds from new decision variables. In this research it will improve this process by using four methods: i) vector transition process is a random of fictitious numbers and takes them to place the desired position, ii) vector exchange processes switch the position of the vectors to disrupt values, iii) vector insertion process moves the position to be inserted prior to the desired position, and iv) is a combination of three methods. 4) Selection: this is the selection of population for the next generation (G+1) by choosing the better answers. This research has designed *Modified Differential Evolution* (MODDE) as shown flow chart in Figure 2.

Figure 2 describes the detailed steps of Modified Differential Evolution (MODDE) as follows:

3.1 Initialization

The program operates a random sampling between 0-1 to give to each array to set the initial target vector; afterwards, array numbers are compared in terms of values and the maximum value of arrays in each row is selected to deliver productivity to each other, occurring between farmers delivering rice paddy to the rice mills and rice mills delivering rice to the exporters and to the wholesale dealers respectively as shown in Table 1.

From Table 1 it is seen that farmers 1 (i = 1) delivers rice paddies to the rice mills 2 (j = 2) due to the highest value in row 1 as 0.46, which corresponds to j = 2. Similarly, farmers 2 to 17 (i = 2 to 17) delivers rice paddies to the rice mills. 1,2, ..., 1,1,1, respectively. The rice mills 1 delivers rice to exporters 1, 4, ...,8, respectively. The rice mills 2 delivers rice to exporters 2, 3, 5, ...,9, 10, respectively. The rice mills 1 delivers rice to wholesale dealers 1 and the rice mills 2 delivers rice to wholesale dealers 2,..., 5 respectively. The objective is then calculated by considering three target equations.

3.2 Mutation

The mutation process can be executed using Equation 1. Three vectors are randomly selected from all vectors that are generated by each iteration to form a mutant vector.

$$V_{i,G+1} = X_{r1,G} + F(X_{r2,G} - X_{r3,G}) \tag{1}$$

It is noted that Xr1, Xr2, Xr3 must be different from vector Xi,g. F is a scaling factor which is used to control the degree of difference of two selected vectors. An example of mutant solution is shown in Table 2.

3.3 Crossover

We will improve the mutant vector by using four methods i) Vector transition process, ii) Vector exchange process, iii) Vector insertion process and iv) A mix. All described in following: i) Vector transition processes: The

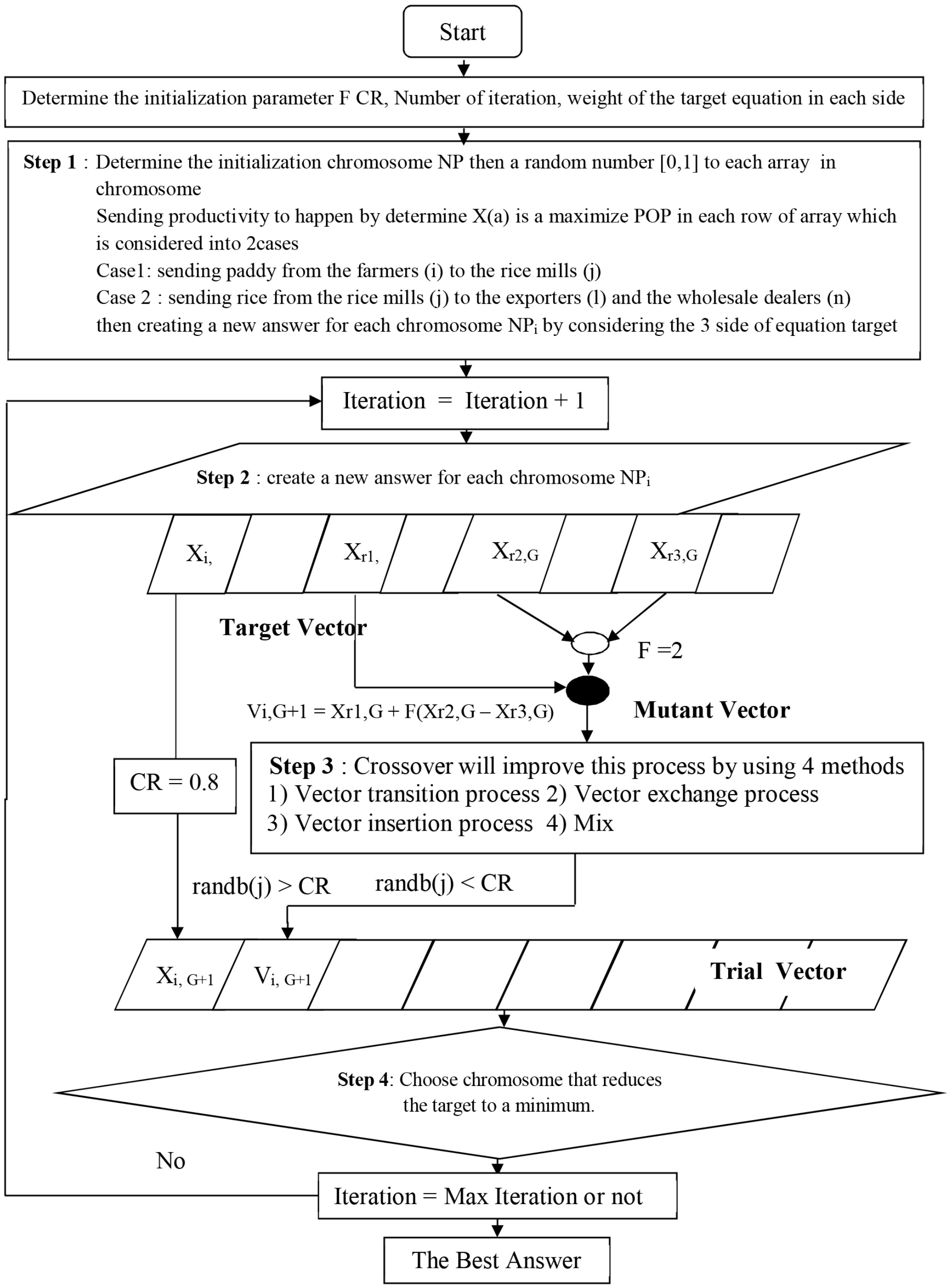

Figure 2. Flow chart of *Modified Differential Evolution* (MODDE).

random number will imaginary rise and then the random numbers is brought to the desired position. 2) Vector exchange process: switch the position of the vector for disturb values. 3) Vector insertion process: the move positions to be inserted a previous to the desired position. 4) Mix: It is a combination of three methods together (Pitakaso, 2014).

The trial vector $U_{j,i,g}$ will be generated from Equation 2. The vector will select the position's value from Xi,g or Vi,g depending on the control parameter CR (crossover rate) and the random number U*j*.

$$U_{j,i,g} \begin{cases} V_{j,i,g} & \text{if } Uj \leq CR \\ X_{j,i,g} & \text{otherwise} \end{cases} \tag{2}$$

Equation 2 explains that when generating the random value of each array value in the vector which lies from 0 to 1, if the value is less than or equal to CR (Crossover Rate) then select the value in the position of the vector obtained from the mutant vector, otherwise choose the value obtained from the target vector.

Table 1. Beginning solution of the MODDE algorithm.

	X(i) (POP if Max, then Send)	
	Chromosome : G, NP.1 (Target Vector)	
	J1	J2
i1	0.27	0.46
i2	0.85	0.13
i3	0.16	0.43
…	……	……
i15	0.47	0.44
i16	0.55	0.53
i17	0.90	0.44
l1	0.19	0.14
l2	0.04	0.09
l3	0.28	0.96
l4	0.56	0.04
l5	0.22	0.26
…	……	……
l8	0.45	0.26
l9	0.38	0.98
l10	0.81	0.92
n1	0.19	0.14
n2	0.04	0.09
…	……	……
n5	0.22	0.26

Table 2. Mutation solution of the MODDE algorithm.

	F = 2	Vi,G+1 = Xr1,G + F(Xr2,G – Xr3,G)
	Mutant Vector	
	J1	J2
i1	0.47	2.02
i2	1.27	-0.65
i3	-1.23	1.33
…	……	……
i15	-0.70	1.65
i16	-0.17	1.41
i17	0.86	-1.04
l1	0.49	1.52
l2	0.14	-0.61
l3	0.20	0.40
l4	0.72	-0.24
l5	1.18	1.20
…	……	……
l8	0.89	0.58
l9	-1.40	0.30
l10	1.43	2.26
n1	-0.11	0.44
n2	-0.88	0.19
…	……	……
n5	1.60	1.22

3.4 Selection

The selection process is used to select the better vector between the target vector Xi,g and the trial vector Ui,g. The better vector will be selected to be the target vector in the next iteration Xi,g+1. The selection process can be executed using Equation 3.

$$X_{i,g+1} \begin{cases} U_{i,g} & \text{if } f(U_{i,g}) \le f(X_{i,g}) \\ X_{i,g} & \text{otherwise} \end{cases} \tag{3}$$

Repeating every chromosome following the mutation process, recombination process and selection process as required (I = I max) when a loop was repeated until the answer is deemed to be the best answer.

4. Experimental Framework and Computational Results

This section presents the experimental framework and compares the different results of the Lingo V.11 program, DE and MODDE approach respectively. It also analyses the case study of transporting rice by MODDE and compares the objective value between Best Practice, DE and MODDE.

4.1 Experimental framework

In case of sample problems of the rice supply chain the framework includes small, medium and large problems as shown in Table 3.

In case of instance problems, the supply chain of rice consists of small, medium and large problems as shown in Table 3. These are solved with a mathematical model by using the LINGO V.11 program with small, medium and large data problems by the weight of each side of objectives being changed in eight levels. The weight is given to only one side of an objective followed by the importance of other objective sides. The sequence of change in each side objective is 80%, 60%, 50%, 40%, 30%, 20%, 10% and 0%.

Then *Modified Differential Evolution* (MODDE) is applied by using Visual Basic C # on a computer, Processor of Intel (R) Celeron (R) D CPU (220 @ 1.2 GHz and RAM of 1.87 GB. The number of chromosomes starts at 10 NP of each case with 15 experiments of each case (following the weight value of objective eq.) and three replications of each experiment at 1,000 iterations.

4.2 Computational results

The results from each program run of instances starting at chromosome 10 NP of each case with 15 experiments of each case following the weight objective equation and 3 replications of each experiment at 1,000 iterations per experiment are summarized in Table 4 for small and medium problems and in Table 5 for large problems.

Table 4 shows the percent average of the finding optimal using DE and MODDE are equal to 88.57% and

Table 3. Conclusion of sizing problem.

Problem size	Number			
	Farmers (I)	Rice Mills (J)	Exporters (L)	Wholesale dealers (N)
Small	20 (A)	4 (A)	10 (A)	4(A)
	20 (B)	4 (B)	10 (B)	4(B)
	25 (A)	5 (A)	11 (A)	5 (A)
	25 (B)	5 (B)	11 (B)	5 (B)
Medium	30 (A)	6 (A)	12 (A)	6 (A)
	30 (B)	6 (B)	12 (B)	6 (B)
	37 (A)	7 (A)	13 (A)	7 (A)
	37 (B)	7 (B)	13 (B)	7 (B)
	57 (A)	8 (A)	14 (A)	8 (A)
	57 (B)	8 (B)	14 (B)	8 (B)
	63 (A)	9 (A)	15 (A)	9 (A)
	63 (B)	9 (B)	15 (B)	9 (B)
	71 (A)	10 (A)	16 (A)	10 (A)
	71 (B)	10 (B)	16 (B)	10 (B)
Large	77 (A)	11 (A)	17 (A)	11 (A)
	93 (A)	12 (A)	18 (A)	12 (A)
	190 (A)	24 (A)	36 (A)	24 (A)

Table 4. Answer results from experiments of small and medium sized problems by using Lingo V.11, DE and MODDE.

Sample Problem	%of the finding optimal using		%of the differential results between			%of the differential Run Time between		
	DE	MODDE	LINGO V.11 and DE	LINGO V.11 and MODDE	DE and MODDE	LINGO V.11 and DE	LINGO V.11 and MODDE	DE and MODDE
4(A)	100	100	0	0	0	- 49.45	-51.23	-3.51
4(B)	100	100	0	0	0	- 68.19	-68.81	-1.96
5(A)	100	100	0	0	0	- 73.19	-73.59	-1.51
5(B)	100	100	0	0	0	- 70.28	-70.78	-1.71
6(A)	86.66	93.33	0.0906	0.0259	0.0906	- 97.96	-97.99	-1.59
6(B)	80.00	86.66	0.1311	0.1009	0.0302	- 88.37	-88.82	-3.86
7(A)	86.66	93.33	0.2342	0.0390	0.1947	- 99.18	-99.20	-2.74
7(B)	86.66	93.33	0.2290	0.1308	0.0979	- 98.09	-98.14	-2.78
8(A)	86.66	86.66	0.1043	0.0626	0.0417	- 98.17	-98.21	-1.80
8(B)	86.66	86.66	0.1612	0.1026	0.0585	- 70.00	-70.54	-1.80
9(A)	80.00	86.66	0.1378	0.0172	0.1204	- 99.24	-99.26	-1.96
9(B)	86.66	93.33	0.1574	0.0242	0.1330	- 99.07	-99.10	-2.73
10(A)	80.00	86.66	0.2556	0.0667	0.1884	- 99.64	-99.66	-1.92
10 (B)	80.00	86.66	0.1705	0.0568	0.1135	- 99.43	-99.45	-1.93
Average	**88.57**	**92.38**	**0.1194**	**0.0448**	**0.0764**	**- 86.45**	**-86.77**	**-2.27**

Note: % of the finding optimal = (Number of the finding optimal / total number)*100 % of the differential results between LINGO V.11 and DE = ((calculated value using DE - calculated value using LINGO V.11) / (calculated value using LINGO V.11))*100 % of the differential Run Time between LINGO V.11 and DE = ((time calculated using DE - time calculated using LINGO V.11) / (time calculated using LINGO V.11))*100.

Table 5. Results of best solutions from experiment of large problems by using Lingo V.11, DE and MODDE.

Sample Problem	% of the finding Best Solutions using		% of the differential results between		
	DE	MODDE	LINGO V.11 and DE	LINGO V.11 and MODDE	DE and MODDE
11 (A)	80.00	86.66	0.0744	0.0446	-0.0297
12 (A)	80.00	86.66	0.0737	0.0246	-0.0491
24 (A)	46.66	53.33	13.2070	6.9064	-5.5656
Average	**68.89**	**75.55**	**4.4517**	**2.3252**	**- 1.8815**

Note: Lingo test by best objective (runtime 48: 00: 00, hh: mm: ss).

92.38% respectively. The percent average differential results between Lingo V.11 and DE, Lingo V.11 and MODDE, DE and MODDE are equal to 0.1194%, 0.0448% and 0.0764%, respectively. The percent average differential run time (in seconds) between Lingo V.11 and DE, Lingo V.11 and MODDE, DE and MODDE are equal to -86.45%, -86.77% and -2.27%, respectively.

Table 5 shows the percent average of finding the best solutions using DE and MODDE are equal to 68.89% and 75.55%, respectively. The percent average of the differential results between LINGO V.11 program and DE, LINGO V.11 program and MODDE, DE and MODDE are equal to 4.4517%, 2.3252% and -1.8815%, respectively. The comparison of performance between LINGO V.11, DE and MODDE of a large problem as shown in Table 6.

The comparison of performance between LINGO V.11, DE and MODDE for a large problem in the limited processing time of 48 hours as shown in Table 6 shows that in the 11 (A) test instances the MODDE algorithms can find a quality solution 0.2649% and -0.0401% away from the objective bound and best objective while using 89.749 seconds to obtain that solution. In the 12 (A) test instance, the MODDE algorithms can find a quality solution 0.0967% and -0.0588% away from the objective bound and best objective while using 171.958 seconds to obtain that solution. In the 24 (A) test instance, the MODDE algorithms can find a quality solution 14.4459% and -10.6525% away from the objective bound and best objective while using 301.915 seconds to obtain that solution. The analysis of the case study of rice transportation by MODDE is shown in Table 7 and can represent the comparison of total objective value between Best Practice, DE and MODDE method in Table 8.

In Table 7 it is shown that farmers will choose to sell rice paddies to the rice mills providing a good price and being nearby. The rice mill will sell rice to exporters and wholesale dealer who provide a good price, live in the neighboring provinces and demand a high amount of rice causing the total objective value to be 32.81 e^8 Baht.

From Table 8 it can be seen that the average percent of the differential results between Best Practice, DE and MODDE are equal to -10.59% and -10.64%, respectively, or that MODDE can reduce the total objective value of the case study of problems by about 10.64%.

Table 6. Comparison of performance between LINGO V.11, DE and MODDE for a large problem.

Sample Problem	Objective Value (e^8 baht)				% of the differential results between LINGO V.11 and DE		% of the differential results between LINGO V.11 and MODDE		Time (sec)	Time (sec)
	Lingo[1a]	Lingo[1b]	DE	MODDE bound	Objective Objective	Best bound	Objective Objective	Best	DE	MODDE
11 (A)	8.9473	8.9746	8.9690	8.9710	0.2425	-0.0624	0.2649	-0.0401	91.383	89.749
12 (A)	10.8615	10.8784	10.869	10.8720	0.0691	-0.0864	0.0967	-0.0588	175.025	171.958
24 (A)	21.2461	27.2143	24.118	24.3153	13.5173	-11.3775	14.4459	-10.6525	338.97	301.915
Average	**13.6850**	**15.6891**	**14.652**	**14.7194**	**4.6096**	**-3.8421**	**7.5589**	**-3.5838**	**201.7927**	**187.874**

Note: [1a]Lingo test by lower bound (runtime 48: 00: 00, hh: mm: ss) . [1b]Lingo test by best objective (runtime 48: 00: 00, hh: mm: ss).

Table 7. Analysis of the rice transportation case study by MODDE.

Farmers	Rice-mills	Exporters and Wholesale dealers
i2 i52	j1(UbonRatchathani)	n2(Bangkok)
i4 i10 i15 i21 i50	j2(UbonRatchathani)	l12(Bangkok)
i5 i6 i7 i8 i12 i16 i18 i19 i20 i24	j3(Ubonratchathani)	l4(Bangkok) l16(Bangkok)
i1 i3 i9 i11 i13 i14 i17 i22 i23 i31 i36 i39 i41 i47 i54 i56 i60	j4(UbonRatchathani)	l8(Chonburi) l9(PathumThani) l10(PathumThani) l14(Bangkok)
i25 i40 i77	j5(Surin)	n10(Nonthaburi)
i27 i28 i32 i76 i78 i90	j6(Surin)	l5(Bangkok) n12(Bangkok)
i29 i30 i34 i35 i37 i38 i64 i83	j7(Surin)	n3(SamutPrakan) n5(SamutPrakan) n7(Nonthaburi) n9 (Chachoenhsao)
i42 i45 i46 i48 i49 i51 i53 i55 i57 i58 i59 i61 i66 i73 i74 i84 i91	j8(RoiEt)	l13(Saraburi) l17(Bangkok) l18(Bangkok) n6(Bangkok)
i43 i44 i72 i85 i88	j9(RoiEt)	l2(Bangkok) l7(Bangkok)
i26 i33 i92	j10(RoiEt)	l1(Bangkok) l6(Bangkok)
i62 i63 i67 i68 i69	j11(NakhonRatchasima)	n1(SamutSakhon) n4(Saraburi) n8(Saraburi)
i65 i70 i71 i75 i79 i80 i81 i82 i86 i87 i89 i93	j12(NakhonRatchasima)	l3(SamutPrakan) l11(Bangkok) l15(SamutSakhon) n11(PathumThani)
Total objective	**32.81 e^8 baht**	

Note: i1 - i24 are farmers in Ubon Ratchathani province, i25 - i41 are farmers in Surin province, i42 - i61 are farmers in Roi Et province, i62 - i93 are farmers in Nakhon Ratchsima province.

Table 8. Comparison of the Different Total Objective Value between Best Practice, DE and MODDE method (e^8 Baht).

Total objective (e^8 baht)			% of the differential results between		
Best Practice	DE	MODDE	Best Practice and DE	Best Practice and MODDE	DE and MODDE
36.72	32.83	32.81	- 10.5936%	-10.6481%	- 0.0609%

5. Conclusions

This research aims to apply *Modified Differential Evolution* (MODDE) method to solve the problem of the supply chain management of rice in lower North-Eastern region of Thailand with many purposes including cost considering the lowest logistical cost, opportunity considering opportunity costs to sell rice at higher prices and time considering time involving in each activity in the logistics and supply chain of rice. To compare the efficiency of solutions with Differential Evolution (DE) and to reduce the logistical costs in the lower North-Eastern region of Thailand, it is found that for the small and medium problems, MODDE can encounter Global Optimal at about average 92.38%. The answers obtained are different at about average 0.0448% to the answers obtained from Global Optimal. MODDE's computing time is also faster than that of the LINGO V.11 program and DE at up to 86.77% on average and 2.27% on average respectively. When the problem is larger, MODDE can also encounter the Best solution different from the objective bound at about 7.5589% on average and different from the best objective by about -3.5838% in average and can also reduce the objective value of case study problem (I93-J12-L18-N12) at about 10.64%.

It can be seen that MODDE can solve whole small, medium and large problems. It is more effectively than the LINGO V.11 program and DE and it can reduce the objective value of case study problems (I93-J12-L18-N12) effectively. Nevertheless, MODDE provides the answer different from the best objective less than the objective bound because MODDE will run towards the best answer by considering X (a) ie. max POP in each row of array and will randomly find answers by each round with set chromosomes starting up to 10 NP and we improved crossover process by using four methods, i) Vector transition process, ii) Vector exchange process, iii) Vector insertion process, and iv) Mix. In addition, the structure of methodology of MODDE is not complicated, it is very flexible due to each round of finding answers can change F and Cr automatically and can also use real numbers in calculation without the need to convert the decision variable into a binary digit, making it find good answers effectively in an appropriate time.

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