Particle Swarm Optimization Solving Various Capacitated P-Median Problem

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Abstract. The purpose of this research is to develop articles algorithm using the Particle Swarm Optimization (PSO) to solve the Capacitated P-Median Problem (CPMP). The development process start from extending the CPMP which considers split order, set up cost and suppliers. The problem is divided into 6 types and using PSO, then improves it in order to improve the efficiency of the PSO. The improved algorithm is called Improved Particle Swarm Optimization (IPSO). The proposed algorithms have been tasted with the test instances in OR-library. The computational results in the problem type 1, PSO can't find the best answer meanwhile IPSO can find the best answer 18 out of 20 which is 90%. The problem in type 2-6 using data set up show that the almost answers of IPSO are better than the answer of PSO as the average different percentage answer between IPSO and PSO is 2.34%.

Keywords: Capacitated P-Median Problem, Particle Swarm Optimization

1. INTRODUCTION

The CPMP was a well-known discrete location problem. We have to partition a set of customers, with a known demand, in p-facilities and consider between capacities that enough supply to a set of customers and minimized total distance. Several researches attempted to add more factors and conditions in order to establish the complex research problems that can represent the real situation. However, the previous researches did not well represent the reality of the problems. This is because the sole a single stage of problem was considered in the researches, the factors of separate delivery, and the construction cost of the factory were not considered in the previous researches.

In this study, in order to select the location with the production limit problem, the researcher has established a research problem considering several factors including, split shipment, factory construction cost, as well as the suppliers. This established multi-stages problem covers the overall factors in the supply chain reflecting the reality is categorized into 6 types: 1. A single-stage problem of location selection with the limit production problem in which P locations are required, 2. A single-stage problem of location selection with the limit production and split shipment problem in which P locations are required, 3. A single-stage problem of location selection with the limit production and split shipment problem in which P locations and the cost of construction are required, 4. A multi-stages problem of location selection with the limit production problem in which P locations are required, 5. A multi-stages problem of location selection with the limit production and split shipment problem in which P locations are required, 6. A multi-stages problem of location selection with the limit production and split shipment problem in which P locations and the cost of construction are required and has developed a heuristic devices meant to be used for a better answer such as Ching-Jung TING et al (2003) used Genetic Algorithms (GA) to solve the CPMP. Masoud Yaghini et al (2013) presented the meta-heuristics that used the Neighborhood Search to initialize solutions and Tabu Search to determine the CPMP. So, in this paper we present heuristic approach for CPMP. To determine this problem, we present the PSO and IPSO to solve it. The researcher has developed a heuristic method that can be used to obtain the best answer to the problem. The research results revealed that 1. The PSO method can be used to solve the 6 types of CPMP effectively, 2. The results obtained from this research are better than those obtained from using the IPSO method.

2. LITERATURE REVIEW

The location selection problem, for a product distribution center, considering an average distributing distance (P-Median Problem), was firstly introduced by Hamiki (1964). However, in the later years, it revealed a weak point of the Himiki's P-Median Problem, in which that it did not consider the fix cost of the center construction. Considering the fix cost construction, the P-Median Problem could become an Uncapacitated Facility Location Problem (UFLP). The problem can get more complex when a size of the center is considered which is called Capacitated P-Median Problem: CPMP.

Ching-Jung TING et al (2003) proposed CPMP addressing the problem, in which if the customer demand is uncertain, after the first facility has already opened, would the next facility at time t=t+1 meet the customer demand. An equation for the problem established considering a lowest of investment at time t+1 including facility construction cost, transportation cost, and annual expense. The study used GA method to solve the problem.

Masoud Yaghini et al (2013) introduced meta-heuristics method, in which that it was developed by combining the Tabu Search and Neighbourhood Search methods to solve CPMP. The study used the Neighbourhood Search method to solve a first stage of the problem then the Tabu Search method was used afterward.

Revelle and Eiselt (2005) suggested that the location consists of the specific 4 problems including 1. selection a client that has already selected the location of the facility or the location is on the transport route 2. a client which would like to seek for a location, 3 an existing location that the facility and 4. a cost for delivery between the facility and the locates customer locations.

I.Kuban Altinel et al (2009) added the complexity to the location selection problem by changing CPMP to Probabilistic Capacitated Multi-Facility Weber Problem (PCMFWP). The study firstly solved the facility location problem and followed by solving the product management problem for the clients who their customers' demands are uncertain. In order to obtain the lowest investment cost, the approximation methods Probabilistic Capacitated ALA (PCALA) were used for solving the problem.

T.Warren Liao (2010) explained the procedure to solve a hybrid problem. The study used Local Search method in which an initial heuristic method, a random walk method, was applied to solve for an interim result. An advance heuristic method, Harmony Search method, was applied afterward in order to obtain the best result for the problem. It revealed that the procedure developed provided a significantly less error percentage compared to other method used.

HAN Dong-xue and WANG Gai-yum (2009) compared the results obtained from GA and PSO methods used to solve a same type of a facility location problem. The result found that PSO method provided a better and faster result compared to GA method are presented in Figure 1.

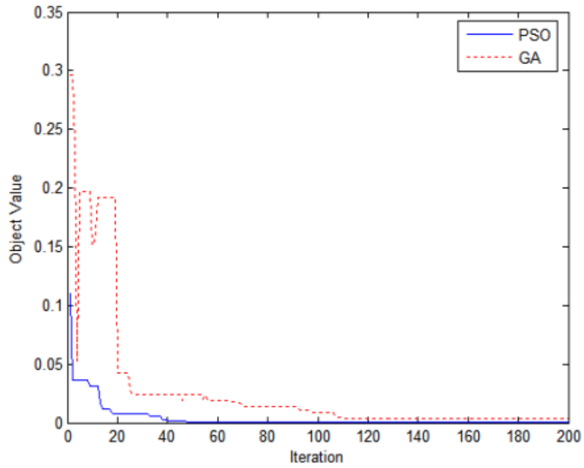

Figure 1: The results obtained from GA and PSO.

Or Liu Li et al (2010) used PSO to solve a problem for facility allocation, the result obtained from the method used was compared to those obtained from alternative heuristic method proposed by Cooper (1960). It found that the result obtained from PSO method is better and faster in all the problem aspects. Moreover, several researchers have used PSO to solve the flow shop sequence dependent group scheduling problems and found that the error percentages of results are significantly less than those obtained from Ant Colony method.

3. THE PROBLEM STATEMENT

The CPMP in this research is categorized into 6 types;

Type 1. A single-stage problem of location selection with the limit production problem in which P locations are required.

$$\text{Min} \sum_{i=1}^{M} \sum_{j=1}^{N} d_{ij} x_{ij} \quad (1)$$

$$\sum_{j} x_{ij} = 1, \quad \forall i \in M \quad (2)$$

$$\sum_{i} g_i x_{ij} \le Q_j y_j, \quad \forall j \in N \quad (3)$$

$$\sum_{j} y_j = P \quad (4)$$

$$x_{ji}, y_j \in \{0,1\}; i \in N, j \in M \quad (5)$$

Type 2. A single-stage problem of location selection with the limit production and split shipment problem in which P locations are required.

$$\text{Min} \sum_{i=1}^{M} \sum_{j=1}^{N} d_{ij} c_{ij} w_{ij} \quad (6)$$

$$\sum_{j} y_j = P \quad (7)$$

$$\sum_{i} w_{ij} \le Q_j y_j, \quad \forall j \in N \quad (8)$$

$$\sum_{j} w_{ij} \ge g_i, \quad \forall i \in M \quad (9)$$

$$y_j \in \{0,1\}; i \in M, j \in N \quad (10)$$

Type 3. A single-stage problem of location selection with the limit production and split shipment problem in which P locations and the cost of construction are required.

$$\text{Min} \sum_{i=1}^{M} \sum_{j=1}^{N} d_{ij} c_{ij} w_{ij} + \sum_{j=1}^{N} f_j y_j \quad (11)$$

$$\sum_{j} y_j = P \quad (12)$$

$$\sum_{i} w_{ij} \le Q_j y_j, \quad \forall j \in N \quad (13)$$

$$\sum_{j} w_{ij} \ge g_i, \quad \forall i \in M \quad (14)$$

$$y_j \in \{0,1\}; i \in M, j \in N \quad (15)$$

Type 4. A multi-stages problem of location selection with the limit production problem in which P locations are required.

$$\text{Min} \sum_{k=1}^{O} \sum_{j=1}^{N} d_{jk} c_{ik} w_{jk} + \sum_{i=1}^{M} \sum_{j=1}^{N} e_{ij} r_{ij} z_{ij} \quad (16)$$

$$\sum_{j} x_{jk} = 1, \quad \forall k \in O \quad (17)$$

$$\sum_{j} y_j = P \quad (18)$$

$$\sum_{k} w_{jk} \le Q_j y_j, \quad \forall j \in N \quad (19)$$

$$\sum_{j} w_{jk} x_{jk} = g_k, \quad \forall k \in O \quad (20)$$

$$\sum_{j} z_{ij} \le A_i, \quad \forall i \in M \quad (21)$$

$$x_{jk}, y_j \in \{0,1\}; i \in M, j \in N, k \in O \quad (22)$$

Type 5. A multi-stages problem of location selection with the limit production and split shipment problem in which P locations are required.

$$\text{Min} \sum_{k=1}^{O} \sum_{j=1}^{N} d_{jk} c_{ik} w_{jk} + \sum_{i=1}^{M} \sum_{j=1}^{N} e_{ij} r_{ij} z_{ij} \quad (23)$$

$$\sum_{j} y_j = P \quad (24)$$

$$\sum_{k} w_{jk} \leq Q_j y_j, \quad \forall j \in N \tag{25}$$

$$\sum_{j} w_{jk} \geq g_k, \quad \forall k \in O \tag{26}$$

$$\sum_{i} z_{ij} \geq Q_j y_j, \quad \forall j \in N \tag{27}$$

$$\sum_{j} z_{ij} \leq A_i, \quad \forall i \in M \tag{28}$$

$$y_j \in \{0,1\}; i \in M, j \in N, k \in O \tag{29}$$

Type 6. A multi-stages problem of location selection with the limit production and split shipment problem in which P locations and the cost of construction are required.

$$\text{Min} \sum_{k=1}^{O}\sum_{j=1}^{N} d_{jk} c_{ik} w_{jk} + \sum_{i=1}^{M}\sum_{j=1}^{N} e_{ij} r_{ij} z_{ij} + \sum_{j=1}^{M} f_j y_j \tag{30}$$

$$\sum_{j} y_j = P \tag{31}$$

$$\sum_{k} w_{jk} \leq Q_j y_j, \quad \forall j \in N \tag{32}$$

$$\sum_{j} w_{jk} \geq g_k, \quad \forall k \in O \tag{33}$$

$$\sum_{i} z_{ij} \geq Q_j y_j, \quad \forall j \in N \tag{34}$$

$$\sum_{j} z_{ij} \leq A_i, \quad \forall i \in M \tag{35}$$

$$y_j \in \{0,1\}; i \in M, j \in N, k \in O \tag{36}$$

where,

i = customer
j = plant
k = supplier
Q_j = Capacity of plant j
d_{jk} = The distance between plant j and customer k
c_{ik} = Cost per piece for delivering products from plant j to customer i
w_{ji} = Number of products deliver from plant j to customer i
e_{kj} = Cost per piece for delivering products from supplier k to plant j
z_{kj} = Number of products deliver from supplier k to plant j
$y_j = \begin{cases} 1 \text{ if plant j is opened} \\ 0 \text{ otherwise} \end{cases}$
P = Number of the opened plant
fj = Cost of construction plant j
A_k = Number of products from supplier k

4. METHODOLOGY

4.1 Particle Swarm Optimization (PSO)

4.1.1 The steps for PSO method for solving single-stage location selection problems is described below;

Step 1: Initialize the parameters at t=1, position and velocity of particle K. the position and velocity of particles are randomly initialized within the search space.

Step 2: Calculate the answer from the position of each particle, evaluate whether the answer is best fit for the problem. The method using for changing position to the answer is different depends on the type of problem.

Step 3: Personal best positions are updated for particles that have a new objective value that is better than the old personal best value.

Step 4: Global best positions are updated for particles that have a new objective value that is better than the old global best value.

Step 5: Update the velocities and positions of all particles using the equations 37 to 40.

Step 6: If all of the conditions are met, the iteration can be stopped. However, if the conditions are not met, set the value of t = t+1 and go back to step 2 to repeat the iteration.

$$v_i^{t+1} = w v_i^t + c_1 R_1 \left(x_{i,Pbest}^t - x_i^t\right) + c_2 R_2 \left(x_{i,Gbest}^t - x_i^t\right) \tag{37}$$

$$x_i^{t+1} = x_i^t + v_i^{t+1} \tag{38}$$

$$w = \frac{\left|(w_w - 0.4)(no.iter - iter_r)\right|}{(no.iter + 0.4)} \tag{39}$$

$$v_i^{t+1} = \begin{cases} v_i^{t+1}, \text{if } v_i^{t+1} \in [v_{min}, v_{max}] \\ v_{min}, v_{max} \quad \text{if } v_i^{t+1} \leq v_{min} \quad \text{or} \quad v_i^{t+1} \geq v_{max} \end{cases} \tag{40}$$

where v_i^{t+1} is the velocity of i^{th} individual at $(t+1)^{th}$ iteration, v_i^t the velocity of i^{th} individual at t^{th} iteration, w the inertia weight, c_1 and c_2 the positive constants, R_1 and R_2 the random number selected between 0 and 1, P_{best} the best position of the i^{th} individual, G_{best} the best position among the individuals (group best) and x_i^t is the position of i^{th} individual at t^{th} iteration.

For random answers can be carried out as follows;

1. Set a particle value for selecting a plant location:

1.1 This is to randomly pick the value for each plant. For example, there are 10 plant, where only 5 plant will be selected for the opening. The random values are between 0-1.

1	2	3	4	5	6	7	8	9	10
0.15	0.24	0.16	0.17	0.38	0.13	0.35	0.89	0.76	0.65

1.2 This step is to orderly arrange the plant' random values from high to low.

8	9	10	5	7	2	4	3	1	6
0.89	0.76	0.65	0.38	0.35	0.24	0.17	0.16	0.15	0.13

The researcher decided this step in order to distribute the opportunity for all plant to be selected evenly. This case, it found that the 5 plant that will be opening are plant 5^{th}, 10^{th}, 9^{th}, 8^{th} and 7^{th} respectively.

1	2	3	4	5	6	7	8	9	10
0	0	0	0	1	0	1	1	1	1

The code can be assigned for the plant selection. The number of particles depends on the designed experiment, however Maurice Clerc (2005) suggested that the particle number can range between 20 to 60 particles, and an appropriate number is 20.

2. Set the velocity, v_i^t (initial velocity): The velocity for each plant is randomly selected, the selected velocities range between v_{min} and v_{max} values.

1	2	3	4	5	6	7	8	9	10
85	40	81	21	92	6	63	13	26	25

3. Set a velocity at v_i^{t+1}: Once the initial velocity and the particle values for x_i^t are obtained, the equation 37 can be used to calculate the velocity of each particle at time t+1.

Then c_1, c_2, R_1, and R_2 values can be substituted into equation 37 to solve for v_i^{t+1} value. The solved v_i^{t+1} value obtained from equation 37 will be then substituted into equation 38 for the assumption number calculation.

1	2	3	4	5	6	7	8	9	10
88	42	89	25	99	15	68	19	27	26

4. Set the particle value at x_i^{t+1}

4.1 Once the velocity at v_i^{t+1} and x_i^t are obtained, the equation 38 can be used to calculate the particle at position x_i^{t+1} and determine the position x_i^{t+1}.

1	2	3	4	5	6	7	8	9	10
88	42	89	25	100	15	69	20	28	27

4.2 The next step is to orderly arrange the x_i^{t+1} values from high to low, transform the values for the selected plant for the opening. This value can be used for the calculation the purpose of the function in the next step.

5	3	1	7	2	9	10	4	8	6
100	89	88	69	42	28	27	25	20	15

⇩

1	2	3	4	5	6	7	8	9	10
1	1	1	0	1	0	1	0	0	0

5. Design an experiment that is appropriate for the customer and PSO method:

5.1 Once the particle value at x_i^t position is assigned for the plant selected for the opening, the locations of the suppliers can be designed by the randomly pick the values for the facilities, the picked values will then be orderly arrange from high to low.

1	2	3	4	5	6	7	8	9	10
0.57	0.88	0.21	0.37	0.47	0.15	0.78	0.41	0.63	0.91

With all 10 numbers will be randomly given to customers 10 and then sorted in descending order random number of customers.

10	2	7	9	1	5	8	4	3	6
0.91	0.88	0.78	0.63	0.57	0.47	0.41	0.37	0.21	0.15

5.2 The customer with highest picked value will have highest possibility to receive the product from the plant, and the customer with the second high pick value will have the second high possibility and so on. It found that the customer that have high to low possibilities to receive the product from the plant are in the following order: customer number 10th, 2nd, 7th, 9th, 1st, 5th, 8th, 4th, 3rd, and 6th, respectively.

5.3 Assign the suppliers (which ways that the customer will be receiving the product from the plant) for the customer by arranging the picked values from high to low values.

6. To decide the amount of product for the customer, this consists of 2 decided options:

6.1 The first option is to decide the amount of products based on one whole shipment. For this option, the plant will deliver the product to the customer in one shipment. The plant will continue deliver the product until there is no sufficient product for the customer.

6.2 The second option is to decide the amount of product based on the separate shipments. For this option, the plant will deliver the product to the customer in separate shipment. The plant will continue deliver the product until there is no product left in the plant.

4.1.2 The PSO method for solving multi-stages location selection problems is described as the followings;

1. Using the steps 1-4 described in the single-stage problem method under the section 4.1.1, however, the suppliers must be selected before the delivery process:

1.1 Random the particle values for the supplier. For example, if there are 10 suppliers, the particle values will range between 0 to1.

1	2	3	4	5	6	7	8	9	10
0.18	0.87	0.57	0.46	0.33	0.68	0.94	0.45	0.56	0.87

1.2 Arrange the picked values from high to low values. The delivery persons that the plant will selected are in the following orders: the supplier numbers 7th, 2nd, 10th, 6th, 3rd, 9th, 4th, 8th, 5th, and 1st, respectively.

7	2	10	6	3	9	4	8	5	1
0.94	0.87	0.87	0.68	0.57	0.56	0.46	0.45	0.33	0.18

1.3 The plant will select the delivery person with the first highest value to deliver the product to the customer until there is no product left for the delivery, thus, the supplier with the second high value will be selected for the product delivery and so on.

2. Decide the amount of product for the customer, this consists of 2 decided options:

2.1 The first option is to decide the amount of products based on one whole shipment. For this option, the plant will deliver the product to the customer in one shipment. The plant will continue deliver the product until there is no sufficient product for the customer.

2.2 The second option is to decide the amount of product based on the separate shipments. For this option, the plant will deliver the product to the customer in separate shipment. The plant will continue deliver the product until there is no product left in the plant.

4.2 Improved Particle Swarm Optimization (IPSO)

For the IPSO method, the researcher have developed and improved the method by adding 7 more steps into the 6 existing standard steps of the method. Therefore the developed method consists of 13 steps. The added steps include step number 2, and 7-12. The developed method and its steps are described below;

Step 1: Initialize the parameters at t=1, position and velocity of particle K. the position and velocity of particles are randomly initialized within the search space.

Step 2: Adjust the c_1 and c_2 parameters using the adjustment method for the result.

Step 3: Calculate the answer from the position of each particle, evaluate whether the answer is best fit for the problem. The method using for changing position to the answer is different depends on the type of problem.

Step 4: Personal best positions are updated for particles that have a new objective value that is better than the old personal best value.

Step 5: Global best positions are updated for particles that have a new objective value that is better than the old global best value.

Step 6: Update the velocities and positions of all particles using the equations 37 to 40

Step 7: Update the global best positions that have a new objective value that is better than the old global best value in step 5.

Step 8: Update the personal best positions that have a new objective value that is better than the old global best value found in step 7.

Step 9: Update the positions that are randomly picked from step 7.

Step 10: Set the personal best and worst values and for the random values picked from step 5 these can be improved using the result improvement process as describe in the following sub-steps:

Set loop process improvement equal to *u* any answer. The position of the best, the worst and the randomly selected values;

Sub-step 1: alternate the answers by using iteration = N (N = number of particles), compare the answers, and select the best answers to be applied in the next step.

Sub-step 2: alternate the answers between each customer and the opened plant, compare the answers, and select the best answer to be used in the next step.

Sub-step 3: alternate the answers between each selected plant for the opening and unselected plant, compare the answers, and select the best answer.

…The *u* loop is completed…

Step 11: Change the positions (from those of the best, the worst and the randomly selected values) to be the answers of the problem and evaluate that answers.

Step 12: Update the global best position, compare the updated values with those obtained from step 5 and 10.

Step 13: If all of the conditions are met, the iteration can be stopped. However, if the conditions are not met, set the value of t = t+1 and go back to step 2 to repeat the iteration.

- For the solving a single stage of location problem using the IPSO method can be done by utilizing steps explained under section 4.1.1
- For the solving multi-stages of location problem using the IPSO method can be done by utilizing steps explained under section 4.1.2

5. COMPUTATIONAL FRAMWORK AND RESULTS

For the single-stage and multi-stages of location problem, the researcher has set the problem that is related and brought to the development of the LINGO V.11 program. This is to be utilized for experiment and development of the Heuristic program, PSO and IPSO methods. The program can be utilized to solving the location problem is developed using Visual C++ software. The research equipment includes Computer hardware and Computer software. The specifications for computer are Intel(R) core I5 CPU, 2.4 GHzs, 4.00GB. The problem is categorized into 6 types and divided into 3 groups: the problem in category 1, the problem in categories 2-3, and the problem in categories 4-6.

5.1 The problem in type 1

The algorithm to be utilized to test with the test instances in OR-Library. The tested problem is P-Median-Capacitated locates in the pmedcap1 folder. This tested problem was developed by Ibrahim H.Osman (1994)consists of 20 sub-problems. The results were compared to those obtained by other researchersusing the parameters in Table 1.

Table 1: Parameters for computational.

Parameter	Value
c_1	0.75
c_2	2.0
w_w	0.75
Number of particles	60

The researched compared the result obtained using a clustering method based on PSO and IPSO to the results obtained are shown in Table 2 and the method used by other researchers, it found that 1. Ibrahim H.Osman and Nicos Christofides (1994) used Hybrid Simulated Annealing and Tabu Search methods to solve the problem. 2. Samad Ahmadi and Ibrahim H.Osman (2005) used Greedy Random Adaptive Search and Adaptive Memory Programming methods to solve the problem. 3. Juan A.Diaz and Elena Fernandez (2006) used a combined method between Scatter Search and Path Relinking methods to solve the problem. 4. Stephan Scheuerer and Rolf Wendolsky (2006) used Scatter Search-Based method. 5. Masoud Yaghini, Mohammad Karimi and Mohadeseh Rahbar (2013) used the combined Heuristic method with Neighborhood Search and Tabu Search techniques.

5.2 The problem in type 2-3

The researcher has divided the problem in this group into 4 sub-problems in order to test with the single-stage problem which there is no supplier involved and to test with the developed algorithm by using the parameters in Table 1 and the results are shown in Table 3.

Table 2: Computational time of type 1.

No.	Ibrahim H.Osman	Samad Ahmadi	Juan A.Diaz	Stephan Scheuerer	Masoud Yaghini	PSO	IPSO
1	713	713	713	713	713	732	713
2	740	740	740	740	740	756	740
3	751	751	751	751	751	785	751
4	651	651	651	651	651	665	651
5	664	664	664	664	664	678	664
6	778	778	778	778	778	805	778
7	787	787	787	787	787	808	787
8	820	820	820.9	820	820	850	820
9	715	715	715	715	715	735	715
10	829	829	831.4	829	829	858	829
11	1006	1006	1006	1006	1006	1064	1013
12	966	966	966	966	966	1005	966
13	1026	1026	1026	1026	1026	1095	1026
14	982	982	983.7	982	982	1030	982
15	1091	1092	1092.2	1091	1091	1148	1091
16	954	954	954	954	954	1005	954
17	1037	1037	1037	1037	1037	1093	1034
18	1045	1045	1045.2	1045	1045	1101	1045
19	1031	1032	1032	1031	1031	1085	1031
20	1005	1012	1006	1005	1005	1063	1023

Table 3: Objective function and Computational time of type 2-3.

No.	Open plant	Customer	%Gap (Lingo vs PSO)		%Gap (PSO vs IPSO)	
			Type 2	Type 3	Type 2	Type 3
1	2,3,4	5	0	0	0	0
2	5,8,10	40	0.007	0.533	0.01	1.547
3	15,20,30	100	0	3.137	0.097	2.167
4	30,40,50	200	0.01	1.867	0.053	2.077
Avg.			0.004	1.384	0.040	1.448

5.3 The problem in categories 4-6

The researcher has divided the problem in this group into 4 sub-problems in order to test with the multi-stage problem which there is suppliers involved and to test with the developed algorithm by using the parameters in Table 1 and the results are shown in Table 4.

Table 4: Objective function and Computational time of type 4-6.

No.	Supplier	Open plant	Customer	%Gap (Lingo vs PSO)			%Gap (PSO vs IPSO)		
				Type 4	Type 5	Type 6	Type 4	Type 5	Type 6
1	5	1,2,3	5	15.14	0	0	16.57	5.22	8.697
2	20	5,8,10	40	38.98	0.487	0.3	4.047	1.197	0.777
3	50	15,20,30	100	0.63	0.58	0.343	0.803	1.097	0.805
4	100	30,40,50	200	0.513	0.543	0.277	0.91	0.55	0.1
Avg.				13.81575	0.4025	0.23	5.5825	2.016	2.59475

6. CONCLUSION

Developing the problem of CPMP for a selection of suitable location problem in this research has considered several parameters including the split shipment, factory construction cost, as well as the suppliers. The problem was divided into 6 types which the PSO, IPSO, and the Lingo program were used to solve the problem. The result showed that the problem in the 1st type was solving using the clustering method based on PSO could not provide the best answer for the problem. While IPSO method based on can provide the 18 best answers out of 20 problems (90%). For the result of the problem type 2-6, if found that the result obtained from the improved method, almost of them, are lower than those obtained from the clustering method based on PSO. The average percentage difference between the answers obtained from two methods is 2.34 percent.

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