CHAPTER IV

RESULTS AND DISCUSSION

This chapter reports a series of two experiments that investigated the performance setting of the matrix-based Genetic Algorithms (m-GA) and appreciated setting of GA parameters and the discussion on experiments is described in last section.

Experiment 1

The objectives of this experiment were to test the m-GA developed in this work for minimizing total transportation cost (the equation 1 described in chapter III) with small size of problem and to determine the GA parameters that achieve the best results.

1. Experimental Design

The experimental work was aimed to investigate the influence of alternative crossover and mutation operations described in previous section by varying the value setting of GA parameters including a combination of population size and number of generations and probabilities of crossover and mutation. The experimental factors and its values considered are shown in Table 19.

Table 19 Experimental factors and its level.

Factors	Levels (coded)	
	Low (-)	High (+)
Population/Generation (P/G)	50/20	20/50
Probability of crossover (%C)	0.6	0.9
Probability of mutation (%M)	0.1	0.5
Crossover operation (COP)	Type I	Type II
Mutation operation (MOP)	Type I	Type II
Chromosome selection (CS)	SUS	RWS

There are entirely six factors to be considered in this work. The first factor is the combination of population size and number of generations (P/G), which determines the total chromosome to be investigated. This factor will be influence on the exploration process of seeking solutions and also delaying the execution time of the computational run. Total amount of chromosomes generated was fixed at 1,000 according to test runs.

The next couple of factors are the probabilities of crossover (%C) and mutation (%M). The values setting of these factors are referred to previous research on appropriate setting of GA parameters (Pongcharoen, et al., 2002) (Pongcharoen & Promtet, 2004). The next couple of factors are the crossover (COP) and mutation operation (MOP). Two types of each COP and MOP described in the aforementioned section are also investigated the impact of its mechanism on the performance of GA to yield optimal solutions. The last factors are the chromosome selections (CS). Two types of each SUS and RWS described in the chapter II.

2. Experimental Analysis

Table 20 shows the analysis of variance (ANOVA) on the experimental factors and their interactions using the computational results obtained. It can be seen that only three main factors including P/G, %M and COP were found statistically significant whilst others remaining factors (%C and MOP) were insignificant with 95% confident interval. These significant factors found were in agreement with previous research (Pongcharoen & Promtet, 2004). It was also found that the random seed, which is not GA parameter, has no impact on the results obtained even through it was statistically significant in previous research (Pongcharoen & Promtet, 2004).

Table 20 Analysis of variance on the experimental results.

Source	DF	SS	MS	F	P
P/G	1	11077563	11077563	20.82	0.000
%C	1	1072563	1072562	2.02	0.158
%M	1	6765062	6765062	12.71	0.000
COP	1	11130250	11130250	20.92	0.000
MOP	1	121000	121000	0.23	0.634
CS	1	10404000	10404000	19.55	0.000
P/G*%C	1	2730063	2730063	5.13	0.025
P/G*%M	1	1105562	1105562	2.08	0.152
P/G*COP	1	625000	625000	1.17	0.280
P/G*MOP	1	240250	240250	0.45	0.503
P/G*CS	1	100000	100000	0.19	0.665
%C*%M	1	495062	495063	0.93	0.336
%C*COP	1	441000	441000	0.83	0.364
%C*MOP	1	324000	324000	0.61	0.437
%C*CS	1	90250	90250	0.17	0.681
%M*COP	1	1369000	1369000	2.57	0.111
%M*MOP	1	625000	625000	1.17	0.280
%M*CS	1	529000	529000	0.99	0.320
COP*MOP	1	430562	430562	0.81	0.370
COP*CS	1	27563	27563	0.05	0.820
MOP*CS	1	1105563	1105563	2.08	0.152
Error	138	73424125	532059		
Total	159	124232437			

Due to the normality assumption within the ANOVA (Montgomery, 2001), the normal probability plot of the residuals created by statistical software package indicated that the residuals are normally distributed. Figure 21 shows the normal probability plot of the residuals.

The main effect plots of the significant and insignificant factors shown in Figure 22 suggest that for the significant factors, the combination of population size and number of generations (P/G) of 50/20, probability of mutation of 0.5 or 50%, crossover operation type I and the chromosome selection of SUS were produced the minimum results. The insignificant factors have to be however set before performing GA. The main effect plots indicate that for the insignificant factors, the probability of crossover should be set to high value (0.9 or 90%) whilst mutation operation type I may be used.

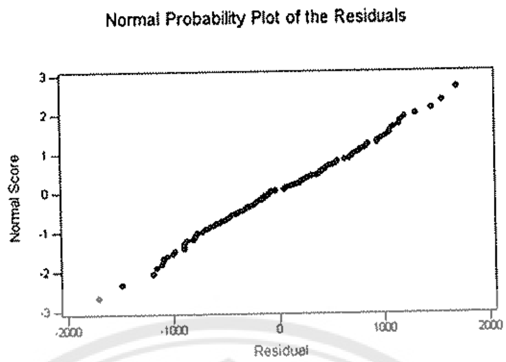

Figure 21 Normal probability plot of the residuals.

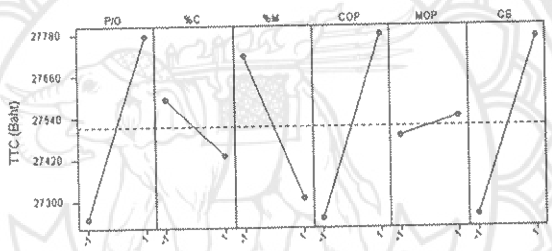

Figure 22 Main effect plots of experimental factors.

Due to the best setting of GA parameters suggested in Figure 22, three further run sets have been made in order to investigate the minimization of the results obtained. The first run set is executed with the best setting of GA parameters previously recommended using the same set of five random seeds used in the main experiment. The second run set is aimed to investigate the influence of the factor P/G since the main effect plot of P/G arisen a question that with limit of 1000 chromosomes generated, whether or not higher population size with lower generations is more desirable than the vice versa? The second run set is therefore performed five times using the similar random seeds with the same parameters setting as the first run set but assign the value of P/G to 500/2. The last run set is planned to consider the setting values of probabilities of crossover (%C) and mutation (%M) due to the main effect plot of %C and %M suggested that the higher values considered should be set to these factors. This run set is therefore executed five times using the same parameters setting applied in the first run set but assigning both values for %C and %M to 1 (100%). The total transportation cost (unit in Baht) of the further run sets are summarized in Table 21.

Table 21 The results obtained from three further run sets.

Seed no.	Run set number		
	1	2	3
1111	26250	29000	26250
2222	26200	28500	26000
3333	25750*	28200	27300
4444	26700	29400	26500
5555	26900	28550	26950
Average	26360	28730	26600

Remark: * indicates the optimal solution.

It can be seen that the first run set has minimum average total transportation cost where the optimal total cost was found at 25750 Baht. This value is the best solution, which was initially identified by linear programming method. This means that the appropriate settings for all factors illustrated by Figure 22 are recommended. The second set of runs yield very poor results. This suggests that increasing too much on the population sizes by reducing number of generation with keeping the same number of chromosomes generated is not suggested. The last run set produces medium quality of results. This proves that increasing the probabilities of crossover and mutation to 1 (100%) does not help the GA process to achieve better results than those obtained from the first run set, which applied the best setting of GA parameters.

Experiment 2

The objectives of this experiment were to test the m-GA developed in this work for minimizing total cost (the equation 2 described in chapter III) with three sizes of problem and to determine the GA parameters that achieve the best results.

Experimental design

All sizes of problem in this experiment were designed to be equal the experimental design of experiment 1. The experimental factors and its values considered are shown in Table 19. This experiment designed half fractional factorial design with five replications was carried out with aimed to investigate the influence of alternative crossover and mutation operations by varying GA parameters and consisted small, medium and large problem.

1. Small problem

The small problem was aimed applying matrix based genetic algorithms (m-GA) to minimize the total cost (equation 2).

Experimental Analysis

Table 22 shows the analysis of variance (ANOVA) on the experimental factors and their interactions using the computational results obtained. It can be seen that only three main factors including P/G, %M and COP were found statistically significant whilst others remaining factors (%C, MOP and CS) were insignificant with 95% confident interval. These significant factors found were in agreement with previous research (Pongcharoen & Promtet, 2004). It was also found that the random seed, which is not GA parameter, has no impact on the results obtained even through it was statistically significant in previous research (Pongcharoen & Promtet, 2004).

Table 22 Analysis of variance on the experimental results

Source	DF	SS	MS	F	P
P/G	1	32715766	32715766	16.67	0.000
%C	1	4472266	4472266	2.28	0.133
%M	1	15221391	15221391	7.76	0.006
COP	1	22015141	22015141	11.22	0.001
MOP	1	5833141	5833141	2.97	0.087
CS	1	3736266	3736266	1.90	0.170
P/G*%C	1	922641	922641	0.47	0.494
P/G*%M	1	13141	13141	0.01	0.935
P/G*COP	1	6951391	6951391	3.54	0.062
P/G*MOP	1	284766	284766	0.15	0.704
P/G*CS	1	1650391	1650391	0.84	0.361
%C*%M	1	4339516	4339516	2.21	0.139
%C*COP	1	87891	87891	0.04	0.833
%C*MOP	1	301891	301891	0.15	0.696
%C*CS	1	123766	123766	0.06	0.802
%M*COP	1	766	766	0.00	0.984
%M*MOP	1	7288891	7288891	3.71	0.056
%M*CS	1	2562891	2562891	1.31	0.255
COP*MOP	1	23766	23766	0.01	0.913
COP*CS	1	147016	147016	0.07	0.785
MOP*CS	1	1097266	1097266	0.56	0.456
Error	138	270843656	1962635		
Total	159	380633609			

Due to the normality assumption within the ANOVA (Montgomery, 2001), the normal probability plot of the residuals created by statistical software package indicated that the residuals are normally distributed. Figure 23 shows the normal probability plot of the residuals.

The main effect plots of the significant and insignificant factors shown in Figure 24 suggest that for the significant factors, the combination of population size and number of generations (P/G) of 50/20, probability of mutation of 0.5 or 50% and crossover operation type I were produced the minimum results. The insignificant factors have to be however set before performing GA. The main effect plots indicate that for the insignificant factors, the probability of crossover should be set to high value (0.9 or 90%), the crossover selection should be set to low value (SUS) whilst mutation operation type II may be used.

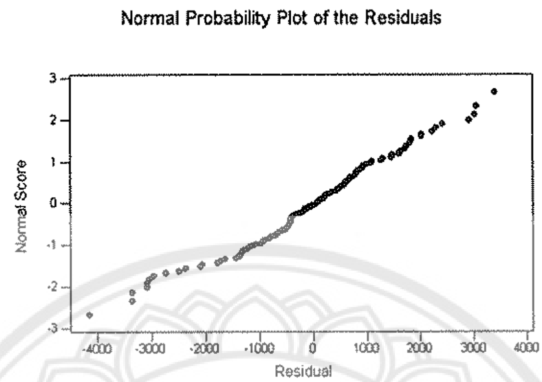

Figure 23 Normal probability plot of the residuals.

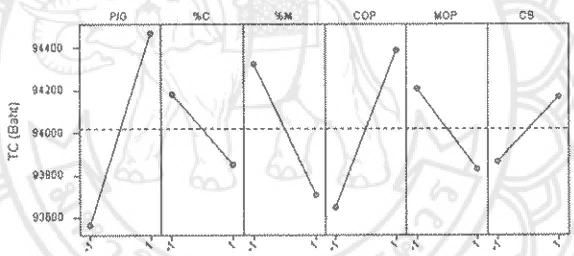

Figure 24 Main effect plots of experimental factors.

Due to the best setting of GA parameters suggested in Figure 24, three further run sets have been made in order to investigate the minimization of the results obtained. The first run set is executed with the best setting of GA parameters previously recommended using the same set of five random seeds used in the main experiment. The second run set is aimed to investigate the influence of the factor P/G since the main effect plot of P/G arisen a question that with limit of 1000 chromosomes generated, whether or not higher population size with lower generations is more desirable than the vice versa? The second run set is therefore performed five times using the similar random seeds with the same parameters setting as the first run set but assign the value of P/G to 500/2. The last run set is planned to consider the setting values of probabilities of crossover (%C) and mutation (%M) due to the main effect plot of %C and %M suggested that the higher values considered should be set to these factors. This run set is therefore executed five times using the same parameters setting applied in the first run set but assigning both values for %C and %M to 1 (100%). The total transportation cost (unit in Baht) of the further run sets are summarized in Table 23.

Table 23 The results obtained from three further run sets.

Seed no.	Run set number		
	1	2	3
1111	90850	90650	90150
2222	88150*	90950	92750
3333	90350	92850	93550
4444	92150	92350	93100
5555	92000	89850	89550
Average	90700	91330	91820

Remark: * indicates the optimal solution.

It can be seen that the first run set has minimum average total cost where the optimal total cost was found at 88150 Baht. The best value is 87500 Baht, which was initially identified by linear programming method. This means that the appropriate settings for all factors illustrated by Figure 24 are recommended. The second set of runs yield very poor results. This suggests that increasing too much on the population sizes by reducing number of generation with keeping the same number of chromosomes generated is not suggested. The last run set produces medium quality of results. This proves that increasing the probabilities of crossover and mutation to 1 (100%) does not help the GA process to achieve better results than those obtained from the first run set, which applied the best setting of GA parameters.

2. **Medium problem**

The medium problem was aimed applying matrix based genetic algorithms (m-GA) to minimize the total cost (the equation 2).

Experimental Analysis

Table 24 shows the analysis of variance (ANOVA) on the experimental factors and their interactions using the computational results obtained. It can be seen that only three main factors including P/G were found statistically significant whilst others remaining factors (%C, %M, COP MOP and CS) were insignificant with 95% confident interval. These significant factors found were in agreement with previous research (Pongcharoen and Promtet, 2004). It was also found that the random seed, which is not GA parameter, has no impact on the results obtained even through it was statistically significant in previous research (Pongcharoen and Promtet, 2004).

Table 24 Analysis of variance on the experimental results.

Source	DF	SS	MS	F	P
P/G	1	319790250	319790250	29.42	0.000
%C	1	72250	72250	0.01	0.935
%M	1	32580250	32580250	3.00	0.086
COP	1	8372250	8372250	0.77	0.382
MOP	1	4900000	4900000	0.45	0.503
CS	1	29929000	29929000	2.75	0.099
P/G*%C	1	22952250	22952250	2.11	0.148
P/G*%M	1	2250	2250	0.00	0.989
P/G*COP	1	2250	2250	0.00	0.989
P/G*MOP	1	8281000	8281000	0.76	0.384
P/G*CS	1	15876000	15876000	1.46	0.229
%C*%M	1	24806250	24806250	2.28	0.133
%C*COP	1	3080250	3080250	0.28	0.595
%C*MOP	1	95481000	95481000	8.79	0.004
%C*CS	1	27889000	27889000	2.57	0.111
%M*COP	1	90250	90250	0.01	0.928
%M*MOP	1	841000	841000	0.08	0.781
%M*CS	1	16000	16000	0.00	0.969
COP*MOP	1	13924000	13924000	1.28	0.260
COP*CS	1	10816000	10816000	1.00	0.320
MOP*CS	1	46010250	46010250	4.23	0.042
Error	138	1499816000	10868232		
Total	159	2165527750			

Due to the normality assumption within the ANOVA (Montgomery, 2001), the normal probability plot of the residuals created by statistical software package indicated that the residuals are normally distributed. Figure 25 shows the normal probability plot of the residuals.

The main effect plots of the significant and insignificant factors shown in Figure 26 suggest that for the significant factor, the combination of population size and number of generations (P/G) of 50/20 was produced the minimum results. The insignificant factors have to be however set before performing GA. The main effect plots indicate that for the insignificant factors, the probability of crossover should be set to low value (0.6 or 60%), probability of mutation should be set to high value (0.5 or 50%), crossover operation type I, the crossover selection should be set to low value (SUS) whilst mutation operation type I may be used.

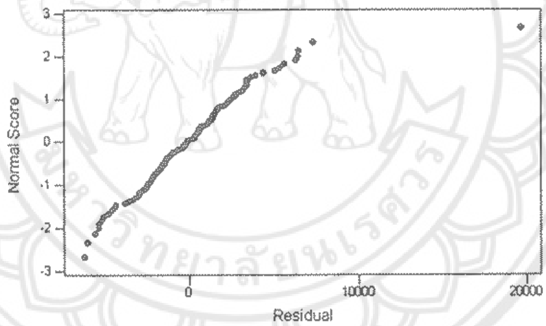

Figure 25 Normal probability plot of the residuals.

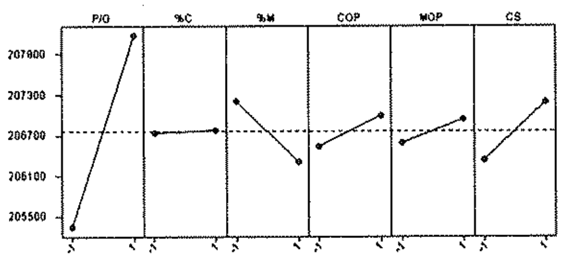

Figure 26 Main effect plots of experimental factors.

Due to the best setting of GA parameters suggested in Figure 26, three further run sets have been made in order to investigate the minimization of the results obtained. The first run set is executed with the best setting of GA parameters previously recommended using the same set of five random seeds used in the main experiment. The second run set is aimed to investigate the influence of the factor P/G since the main effect plot of P/G arisen a question that with limit of 1000 chromosomes generated, whether or not higher population size with lower generations is more desirable than the vice versa? The second run set is therefore performed five times using the similar random seeds with the same parameters setting as the first run set but assign the value of P/G to 500/2. The last run set is planned to consider the setting values of probabilities of crossover (%C) and mutation (%M) due to the main effect plot of %C and %M suggested that the higher values considered should be set to these factors. This run set is therefore executed five times using the same parameters setting applied in the first run set but assigning both values for %C and %M to 1 (100%). The total transportation cost (unit in Baht) of the further run sets are summarized in Table 25.

Table 25 The results obtained from three further run sets.

Seed no.	Run set number		
	1	2	3
1111	203600	204000	202400
2222	204500	204400	202500
3333	206300	199600*	204900
4444	203900	203300	205600
5555	208000	200200	203500
Average	205260	202300	203780

Remark: * indicates the optimal solution.

It can be seen that the second run set has minimum average total cost where the optimal total cost was found at 199600 Baht. The best value is 187800 Baht, which was initially identified by linear programming method. This means that the appropriate settings for all factors illustrated by Figure 26 are recommended. The first set of runs yield very poor results. This suggests that increasing too much on the population sizes by reducing number of generation with keeping the same number of chromosomes generated is not suggested. The last run set produces medium quality of results. This proves that increasing the probabilities of crossover and mutation to 1 (100%) does not help the GA process to achieve better results than those obtained from the first run set, which applied the best setting of GA parameters.

3. Large problem

The Large problem was aimed applying matrix based genetic algorithms (m-GA) to minimize the total cost (equation 2).

Experimental Analysis

Table 26 shows the analysis of variance (ANOVA) on the experimental factors and their interactions using the computational results obtained. It can be seen that only three main factors including P/G, COP and CS were found statistically significant whilst others remaining factors (%C, %M and MOP) were insignificant with 95% confident interval. These significant factors found were in agreement with previous research (Pongcharoen and Promtet, 2004). It was also found that the random seed, which is not GA parameter, has no impact on the results obtained even through it was statistically significant in previous research (Pongcharoen and Promtet, 2004).

Table 26 Analysis of variance on the experimental results.

Source	DF	SS	MS	F	P
P/G	1	3456810563	3456810563	62.32	0.000
%C	1	78820563	78820562	1.42	0.235
%M	1	164633063	164633062	2.97	0.087
COP	1	1880326562	1880326562	33.90	0.000
MOP	1	263425563	263425563	4.75	0.031
CS	1	908685563	908685563	16.38	0.000
P/G*%C	1	27972563	27972563	0.50	0.479
P/G*%M	1	19810562	19810562	0.36	0.551
P/G*COP	1	49395063	49395063	0.89	0.347
P/G*MOP	1	106439063	106439063	1.92	0.168
P/G*CS	1	4455563	4455563	0.08	0.777
%C*%M	1	45262563	45262563	0.82	0.368
%C*COP	1	52555563	52555563	0.95	0.332
%C*MOP	1	14945062	14945062	0.27	0.605
%C*CS	1	495063	495062	0.01	0.925
%M*COP	1	79947563	79947563	1.44	0.232
%M*MOP	1	6123063	6123063	0.11	0.740
%M*CS	1	60639062	60639062	1.09	0.298
COP*MOP	1	195143063	195143063	3.52	0.063
COP*CS	1	126563	126563	0.00	0.962
MOP*CS	1	15687563	15687563	0.28	0.596
Error	138	7654867125	55470052		
Total	159	1.5087E+10			

Due to the normality assumption within the ANOVA (Montgomery, 2001), the normal probability plot of the residuals created by statistical software package indicated that the residuals are normally distributed. Figure 27 shows the normal probability plot of the residuals.

The main effect plots of the significant and insignificant factors shown in Figure 28 suggest that for the significant factors, the combination of population size and number of generations (P/G) of 50/20, crossover operation type I, mutation operation type I and crossover selection of SUS were produced the minimum results. The insignificant factors have to be however set before performing GA. The main effect plots indicate that for the insignificant factors, the probability of crossover should be set to high value (0.9 or 90%) whilst the probability of mutation should be set to high value (0.5 or 50%) may be used.

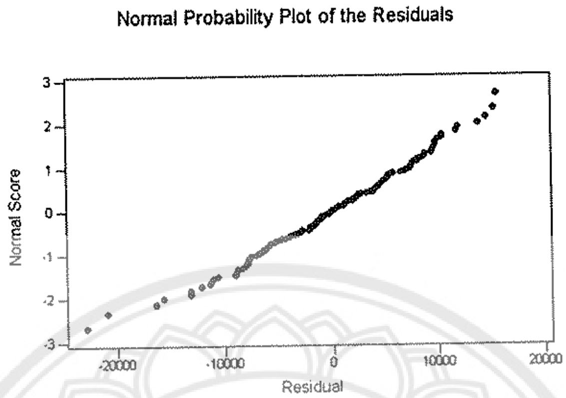

Figure 27 Normal probability plot of the residuals.

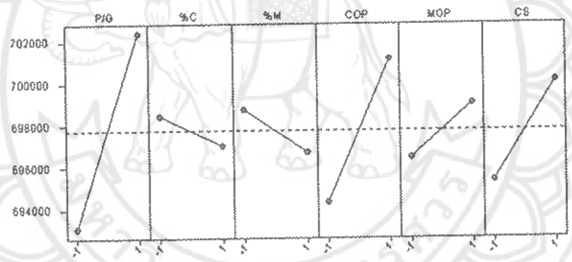

Figure 28 Main effect plots of experimental factors.

Due to the best setting of GA parameters suggested in Figure 28, three further run sets have been made in order to investigate the minimization of the results obtained. The first run, the second run and the third run set as same as experiment of medium problem. The total cost (unit in Baht) of the further run sets are summarized in Table 27.

Table 27 The results obtained from three further run sets.

Seed no.	Run set number		
	1	2	3
1111	682000	682500	688500
2222	682200	689600	685800
3333	690300	691800	688000
4444	685300	685700	691800
5555	674300*	685600	688000
Average	682820	687040	688420

Remark: * indicates the optimal solution.

It can be seen that the first run set has minimum average total transportation cost where the optimal total cost was found at 674300 Baht. This means that the appropriate settings for all factors illustrated by Figure 28 are recommended. The second set of runs yield very poor results. This suggests that increasing too much on the population sizes by reducing number of generation with keeping the same number of chromosomes generated is not suggested. The last run set produces medium quality of results. This proves that increasing the probabilities of crossover and mutation to 1 (100%) does not help the GA process to achieve better results than those obtained from the first run set, which applied the best setting of GA parameters.

Discussion on Experiments

This section was concluded about the experimental results of GA and LP (Show in table 28) and the comparison of GA parameters in experiment 1 and 2 (Show in table 29).

Table 28 The near optimum solution of GA with three sizes of logistics problems.

Experiment No.	Problem size	GA	LP	% Near optimum
		Near optimum Solution	Best Solution	
1	Small	25,750	25,750	0.00%
2	Small	88,150	87,500	0.74 %
	Medium	199,000	187,800	5.96 %
	Large	674,300	-	-

Table 28 shows the best solution of LP and the efficiency of GA to find the near optimum solution with three sizes of logistics problems. The best solutions for small and medium size problems had been initially identified by LP using What'sBest! software package. However, the best solution of the large size problem can not be identified since the LP software used in this work is student version.

According to the minimizing total transportation cost, the best solution of LP was found at 25,750 ฿ and the near optimum solution of GA was found at 25,750 ฿ too. The percentage of the near optimum solutions of GA was found at 0.00%. Though, LP and GA were found the best result of total transportation cost at 25,750 ฿ but GA found the number of products flow which were distributed in difference routes on the small size problem (See optimum solutions in appendix B). The processes of the m-GA in this work were convinced to find the near optimum solution in the next experiment.

For the small size problem with minimizing total cost, LP found the best solution at 87,500 ฿ and GA found the near optimum solution at 88,150 ฿. The percentage of the near optimum solutions of GA was found about 0.74%. For the medium size problem, LP found the best solution at 187,800 ฿ and GA found the near optimum solution at 199,000 ฿. The percentage of the near optimum solutions of GA was found about 5.96%. It can be seen that the percentage of the near optimum solution is greater with the problem size. This means that the change of getting optimum solutions is low when the solution space is increased.

Table 29 The comparison of GA parameters.

Experiment No.	Problem size	GA parameters					
		P/G	%C	%M	COP	MOP	CS
1	Small	Low	High	High	Low	Low	Low
2	Small	Low	High	High	Low	High	Low
	Medium	Low	Low	High	Low	Low	Low
	Large	Low	High	High	Low	Low	Low

Remark: the significant factors found in each experiment are indicated using underline

Table 29 shows the best setting of GA parameters investigated in both experiments. In the experiment 1, it was found that the combination of population size and number of generations (P/G) of 50/20, probability of mutation of 0.5 or 50%, crossover operation type I and chromosome selection type I were produced the minimum results. For the small size of experiment 2, it was found that the combination of population size and number of generations (P/G) of 50/20, probability of mutation of 0.5 or 50% and crossover operation type I were produced the minimum results. For the medium size, it was found that the combination of population size and number of generations (P/G) of 50/20 was produced the minimum results. For the large Size, it was found that the combination of population size and number of generations (P/G) of 50/20, crossover operation type I, mutation operation type I and chromosome selection of SUS were produced the minimum results.

From both experiments in Table 29, it can be seen that the amount of significant factors were not affected by problem size. However, the best setting of all significant factors found in each problem size were in agreement, which are P/G, and COP of 50/20 and type I crossover respectively.

According to the results from Table 29, significant and insignificant factors were found the combination of population size and number of generation (P/G), probability of mutation (%M), crossover operation (COP) and chromosome selection (CS) of low, high, low and low, respectively.

Therefore, the combination of population size and number of generation (P/G) was the most important parameter of GA since the parameter was significant in all problem sizes whilst the probability of crossover (%C) has no influence.