Experiments and results

This chapter presents the basic description of how program work and how to do experiments. There are two objectives for the project namely the minimisation of the completion times of the project plans and take into account the robustness of the project plans. The experiments of this project use two programs which are the Genetic Algorithm and the (1+1) Evolutionary Algorithm. Both programs focus on two objectives of the. The results of the experiments from the programs may be presented by line graphs and boxplots.

For the minimisation of the completion times, both programs calculate to give the fitness values based on the fitness function(fitness1). For the robustness of the project plans, the programs may add the noise the completion time to get the fitness values which based on the fitness function(fitness2). The results of both programs are considered the minimisation of the completion times and are taken into account the robustness of the project plans.

In experiments of the project, All data of the sample project plan has to set on both programs to identify the essential data and three constraints. The programs may run 2000 iterations. The works of two programs may have some different processes which based on Genetic Algorithm and (1+1) Evolutionary Algorithm. There is the explanation of the main works of two programs as following:

Genetic Algorithm (The GA)

Minimisation of the completion times

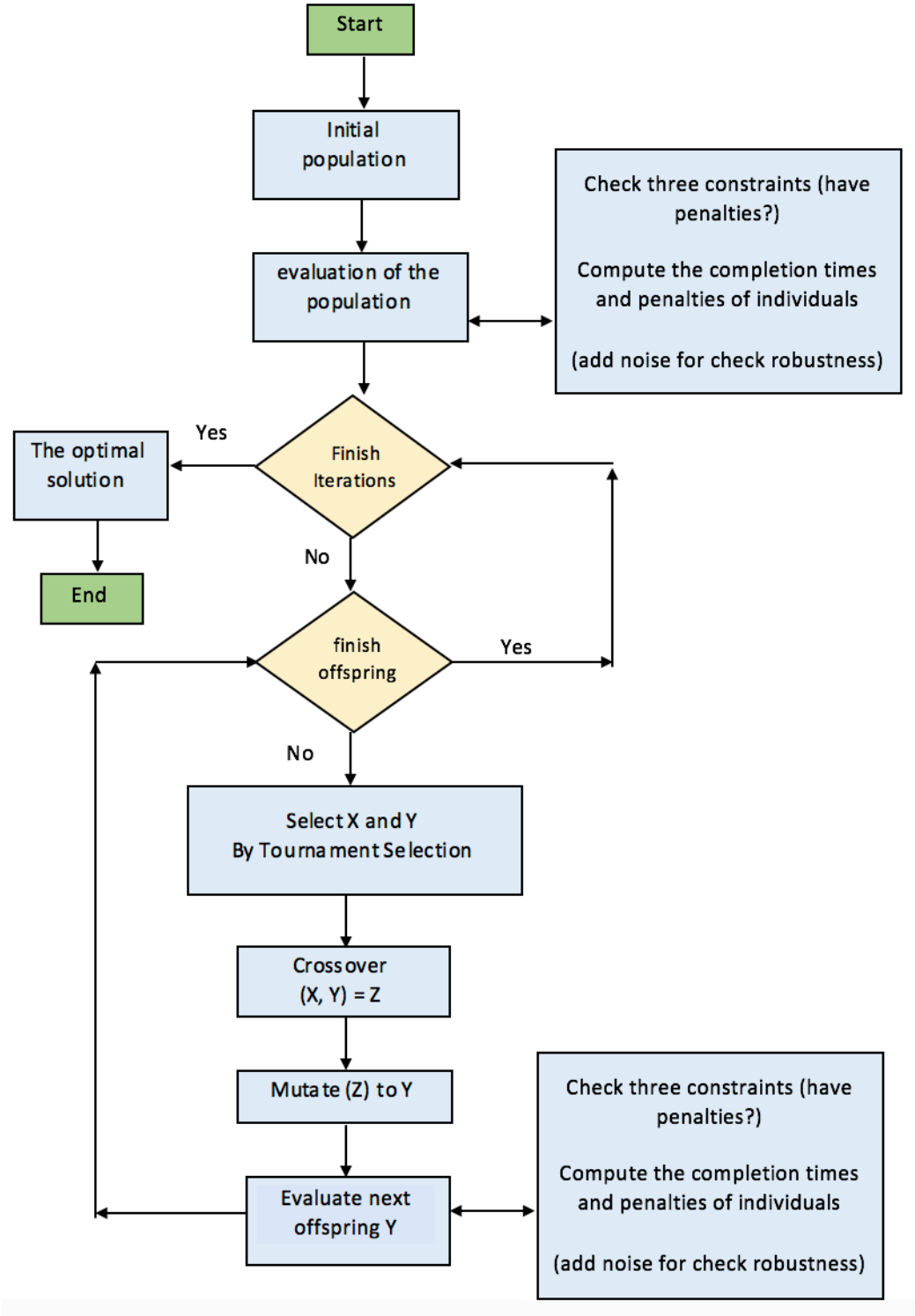
1. Selection: Two individuals by tournament selection.
2. Program running: The program evaluates the initial population. Then the program goes forward to the main program. In the loop, the program chooses two parents by tournament selection. Two parents are taken in the steps of crossover, mutation and evaluation respectively to gain the next offspring. When evaluation completes all offspring for the next iteration. The program may run in 2000 iterations. Therefore, when the program completes 2000 iterations, the program may present the project plan in the last iteration.

3. Output: The project plan in the last iteration, the average of all fitness and the fitness value.

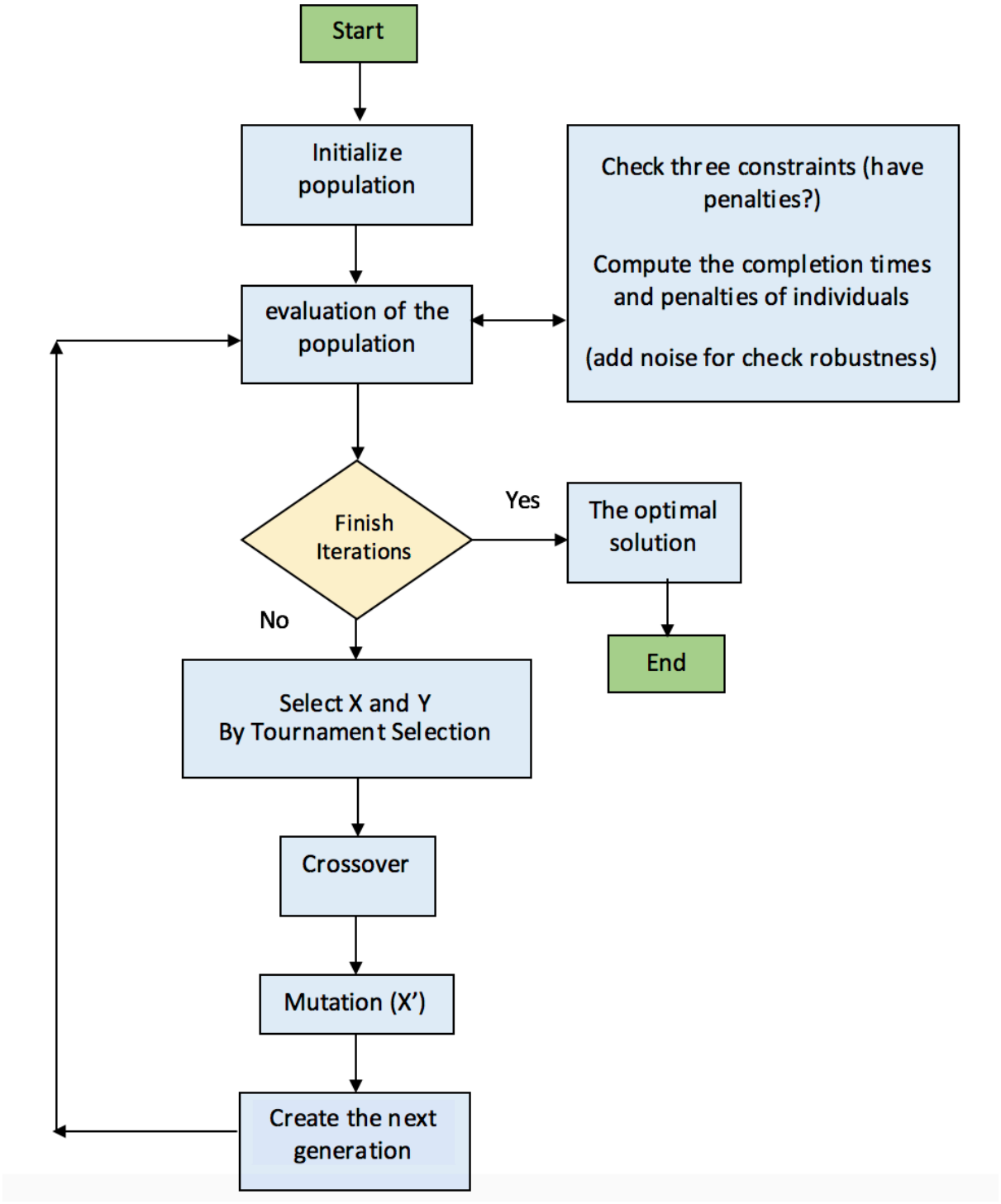
Robustness

1. Selection: Two individuals by tournament selection.
2. Program running: The program may run as same as the program run for minimisation of the completion times. However, there is a random number (a noise) that is added in evaluation. The noise refers the unexpected resources which may occur in the project plans when the program running.
3. Output: Output: The project plan in the last iteration, the average of all fitness and the fitness value.

Moreover, the work of the GA is shown in Figure1.



ASK Supervisor: Which diagram is better?



ASK Supervisor: Which diagram is better?

Figure 1. The work of the GA.

(1+1) Evolutionary Algorithm (The (1+1) EA)

Minimisation of the completion times

1. Selection: one individual at random.
2. Program running: The program chooses an individual randomly. The individual is mutated to a new individual. The program has two individuals now namely old individual and new individual. After that, the program calculates the completion times of both individuals and evaluate the fitness values of individuals. The program may keep the better individual which based on the fitness values of each individual. The better individual may be in the next iteration. The program runs in 2000 iterations. Therefore, when completed 2000 iterations, the program may present the project plan which has the lowest completion time.
3. Output: The project plan in the last iteration, the average of all fitness and the fitness value.

Robustness

1. Selection: one individual is the project plans encoding.
2. Program running: the program may run as same as the program run for the minimisation of the completion times. However, there is a random number (a noise) that is added in each iteration. Noises refer to the unexpected resources which may occur in the project plans when the program running.
3. Output: The project plan in the last iteration, the average of all fitness and the fitness value.

Moreover, the work of the (1+1) EA is shown in Figure2.

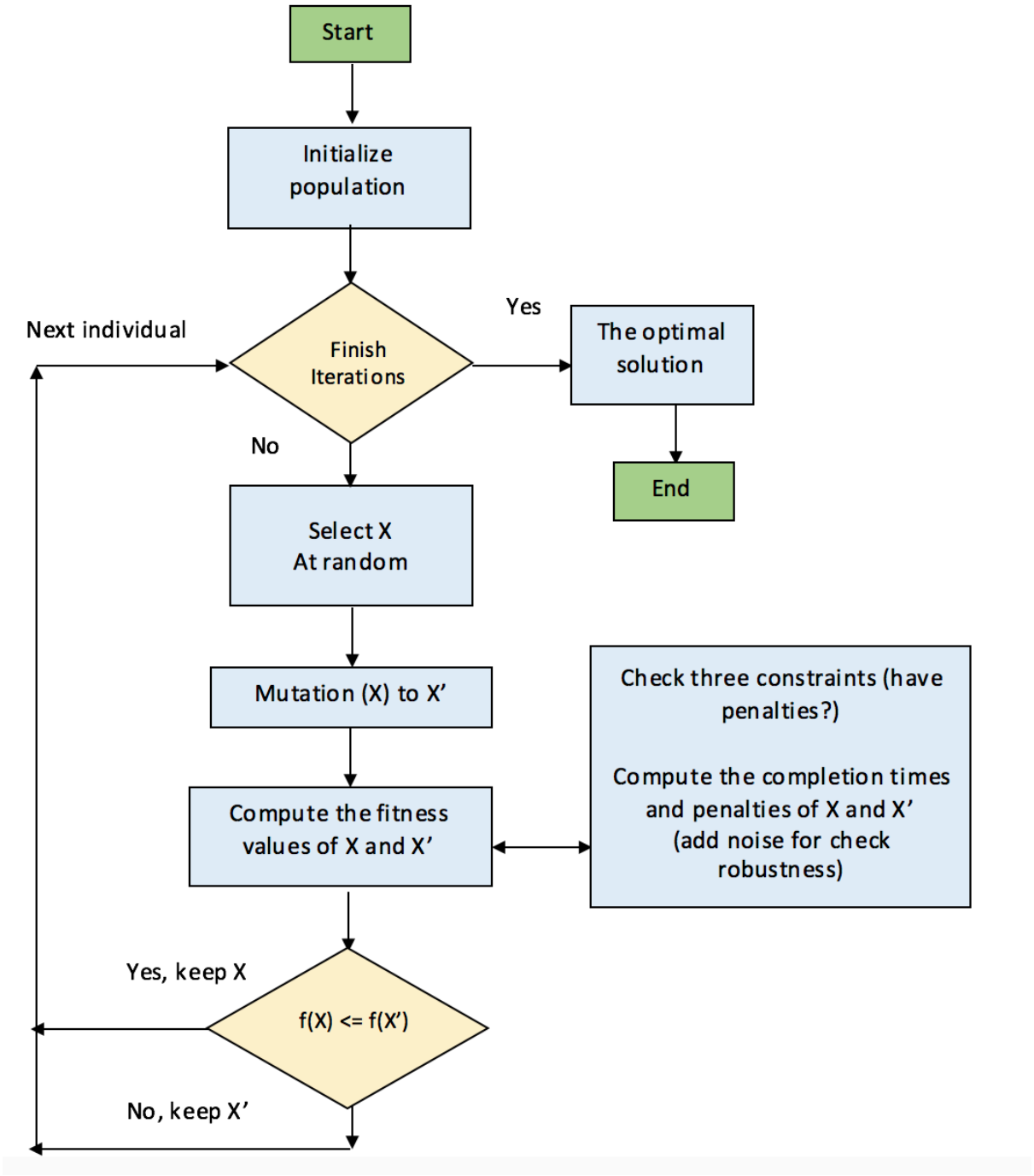


Figure 2. The work of the (1+1) EA.

Experiments and results of the project.

The presentations of the results of the GA and (1+1) EA based on the experiments of work. The main results are the completion times of the possible project plans in 2000 iterations. The completion times in every iteration are displayed in the line graphs. For any charts in the experiments, the X-axis is the number of iterations (2000 iterations) and the Y-axis is the values of the completion times (days). There are two experiments for the objectives of the project as follows:

1. Experiment 1: To minimise the completion times and compare the completion times of the project plans between the GA and (1+1) EA.
2. Experiment 2: To consider the robustness of the project plans and compare the different completion times between the GA and (1+1) EA when considering in the robustness of the project plans.

Moreover, there are three interesting experiments for changing the resources in the project plans. If the resources of the project plans are changed, how to affect the completion times of the project plans in the GA. Three experiments are as follows:

1. Experiment 3: Changing the duration times of the project plans.
2. Experiment 4: Changing work packages of the project plans.
3. Experiment 5: Changing the dependencies of the project plans.

The description of all experiments is presented below.

Experiment 1: Minimisation the completion times of the project plans by using the GA and (1+1) EA with 2000 iterations.

The experiment to minimise the completion times of the project plans regards the results of two programs. The GA and (1+1) EA may run and record the completion times and the project plans encoding (individuals). The programs run the results of the completion times of the project plans from high to lower results. In other words, the high completion times may be minimised to the lower completion times until finish 2000 iterations. The programs may run 10 times for collecting the data to analyse the minimisation. The line graphs and boxplots present these results.

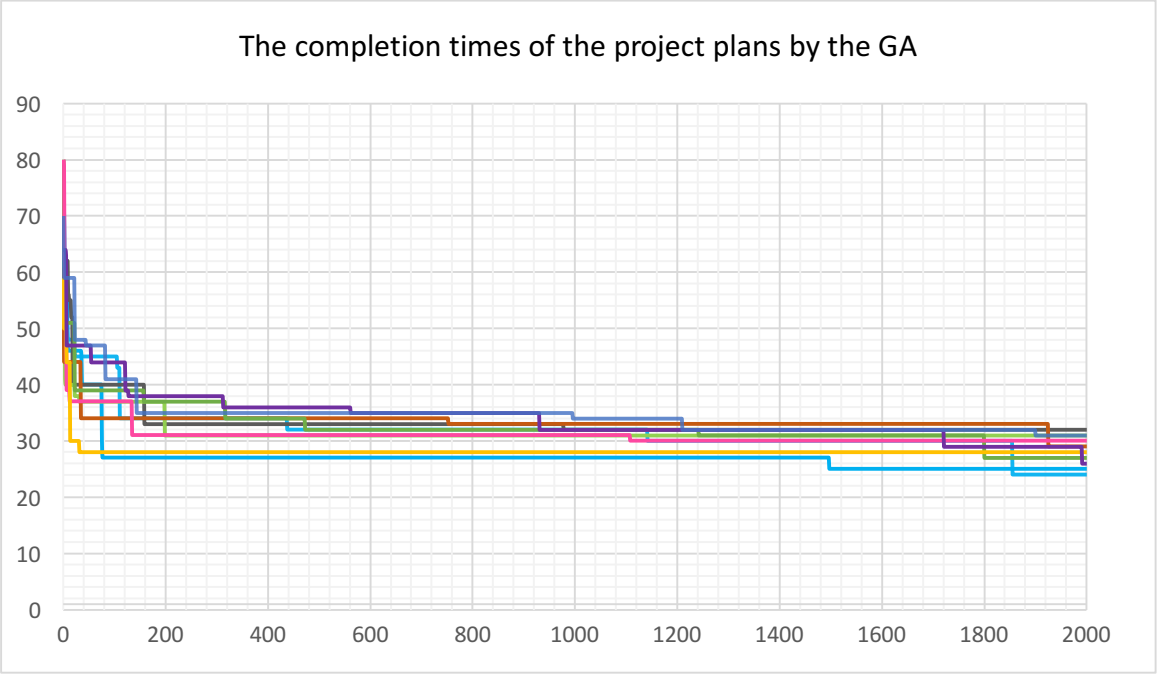


Figure 3. The completion times in 2000 iterations by the GA (10 running times).

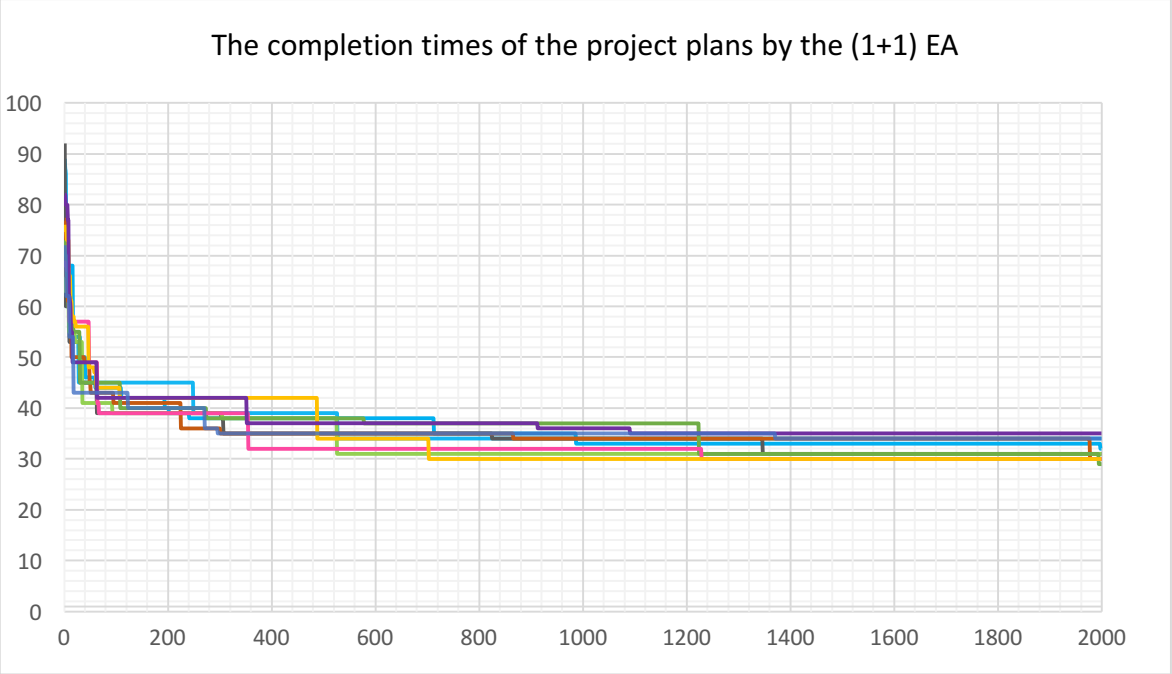
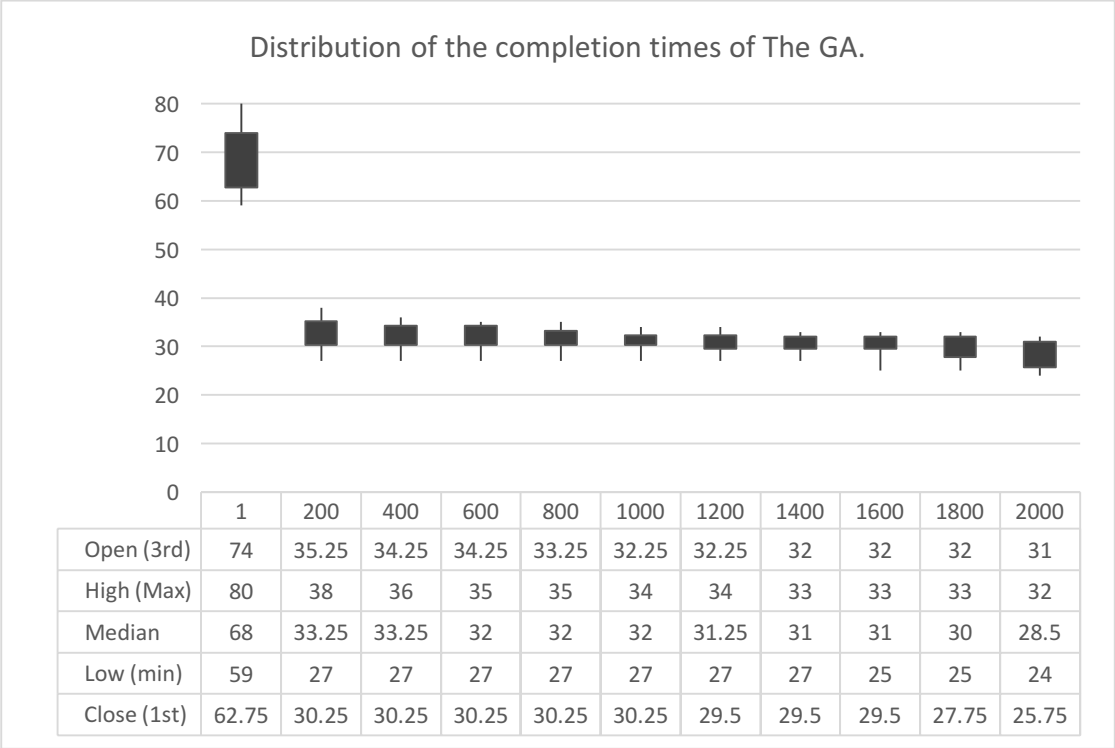


Figure 4. The completion times in 2000 iteration by the (1+1) EA (10 running times).

The line graphs illustrate the results of the different completion times of the project plans in 2000 iterations. The line graphs in Figure 3 and Figure 4 show the results of the GA and (1+1) EA respectively. The line graphs present the results in 10 running times.

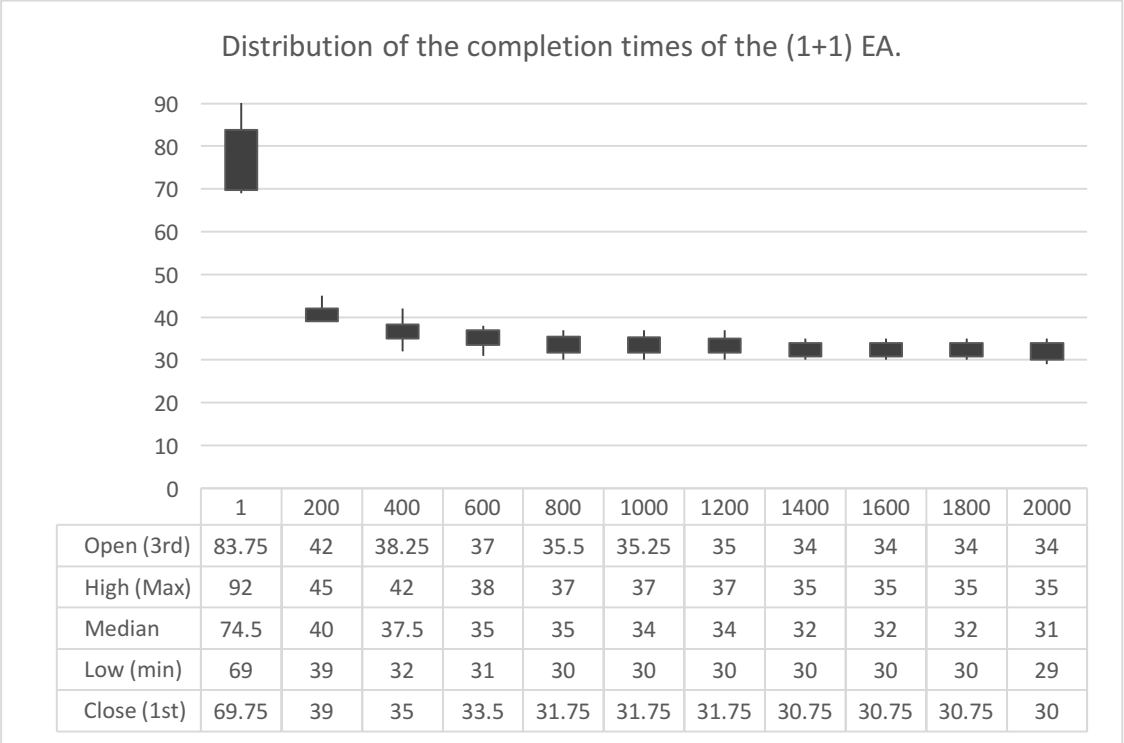
In Figure 3 and Figure 4, the line graphs display that the results decrease rapidly at first and then go down slowly until end 2000 iterations. However, the completion times of the GA falls lower than 40 days before 200 iterations while the completion times of the (1+1) EA reduces lower than 40 days at 500 iterations. After 1800 iterations, the results of the GA sink again and the lowest completion time is 24 days, while the results of the completion times of the (1+1) EA remains nearly 30 days.

In addition, the results of the completion times in 10 running times show in the boxplots. The boxplots distribute the data of the different completion times with 2000 iterations. The boxplot in Figure 5 is the results of the GA in 10 running times. The results of the (1+1) EA also present in Figure 6 as well. The boxplots show some specific data of the completion times such as medians, lowest, and highest of the completion times in every 200 iterations.



	1	200	400	600	800	1000	1200	1400	1600	1800	2000
Open (3rd)	74	35.25	34.25	34.25	33.25	32.25	32.25	32	32	32	31
High (Max)	80	38	36	35	35	34	34	33	33	33	32
Median	68	33.25	33.25	32	32	32	31.25	31	31	30	28.5
Low (min)	59	27	27	27	27	27	27	27	25	25	24
Close (1st)	62.75	30.25	30.25	30.25	30.25	30.25	29.5	29.5	29.5	27.75	25.75

Figure 5. Distribution of the completion times of The GA.



	1	200	400	600	800	1000	1200	1400	1600	1800	2000
Open (3rd)	83.75	42	38.25	37	35.5	35.25	35	34	34	34	34
High (Max)	92	45	42	38	37	37	37	35	35	35	35
Median	74.5	40	37.5	35	35	34	34	32	32	32	31
Low (min)	69	39	32	31	30	30	30	30	30	30	29
Close (1st)	69.75	39	35	33.5	31.75	31.75	31.75	30.75	30.75	30.75	30

Figure 6. Distribution of the completion times of the (1+1) EA.

In first iteration, the GA in Figure 5 shows the median of the completion time at 68 while the median of the completion time of the (1+1) EA in Figure 6 is 74.5 which higher than the median of the GA. The median of the completion times in the GA fall lower 40 since 200 iterations while the medians of the completion times in the (1+1) EA reduce under 40 about 400 iterations. Furthermore, the boxplot of the GA in 2000 iterations drops again till lower than 30 while the results of the (1+1) EA at 2000 iterations still stable at 30 days.

Hence, the GA and (1+1) EA can minimise the number of the completion times in 10 running times. The GA can minimise the completion times of the project plans faster than the (1+1) EA.

Experiment 2: Considering the robustness in the project plans by using the GA and (1+1) EA with 2000 iterations.

In the robustness, we consider when unexpected resources occur in the project plans. We specify any unexpected resources as the number of noises. When we add any noises into the project plans, then the results of the completion times will contain unexpected resources. If unexpected resources do not affect to increase the completion times of the project plans which based on three constraints too much, it means that the project plans are robustness.

We identify the noise at random which based on the maximum duration of one work package in the sample project plan (WP3 = 9 days). The noise is the number between 0 and 9. The line graphs in Figure 7 (the GA) and Figure 8 (the (1+1) EA) illustrate the different results between the completion times with noises and the completion times without noises. Overall, the completion times without noises and the completion times with noises in both programs are quite similar. However, in these results, the noise that based on the highest duration of the work package in the sample project plan is just a small number.

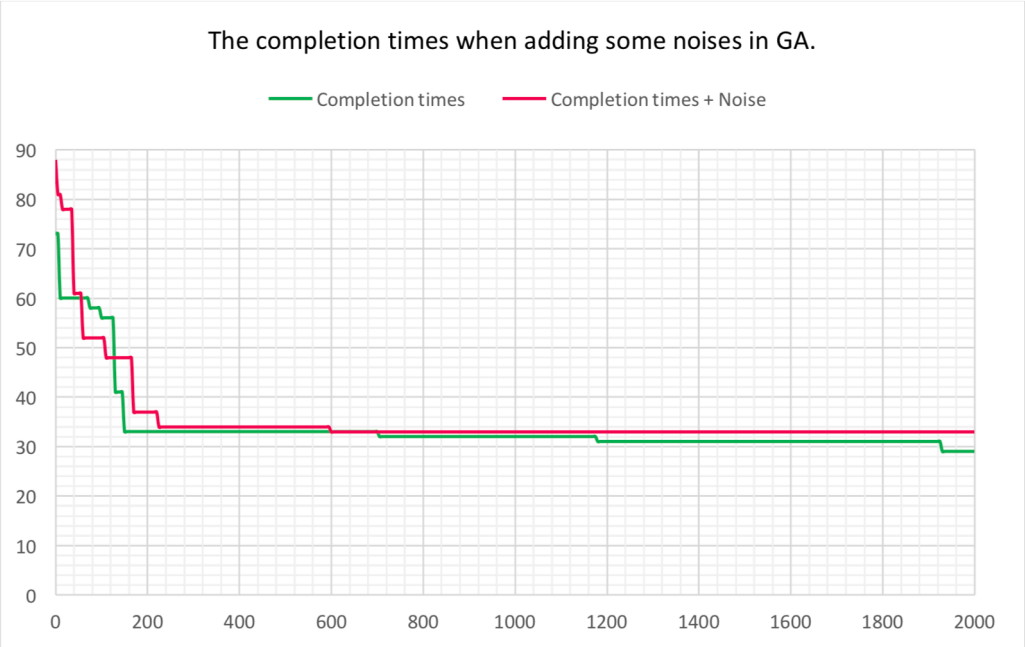


Figure 7. The results of the completion times with/without noises in the GA.

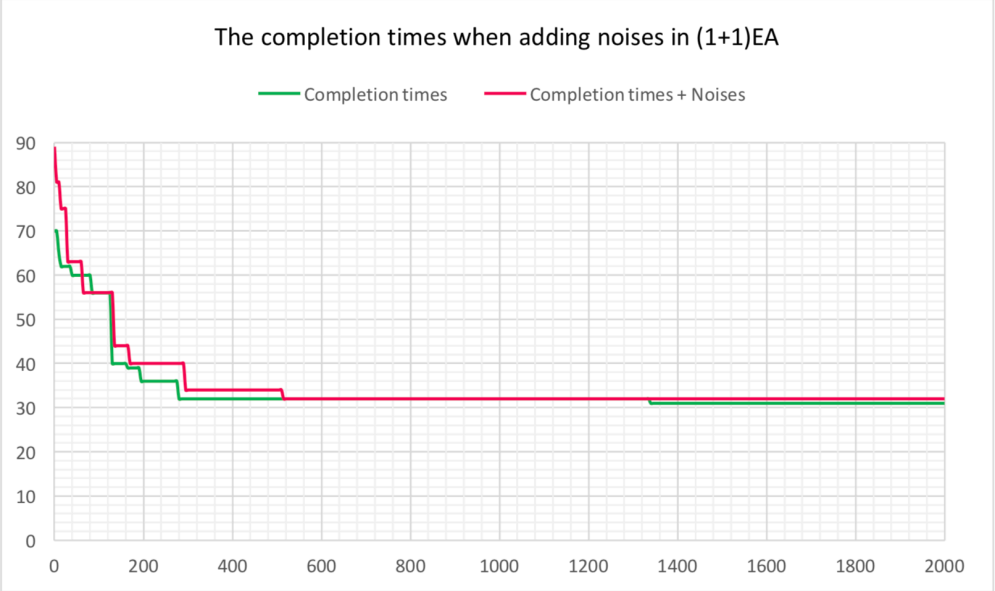


Figure 8. The results of the completion times with/without the noises in the (1+1) EA.

Interestingly, we try to add the noise as the random number between 0 and 20 for looking at the results of the completion times that run in 10 times. The results of the completion times are shown in Figure 9 and Figure 10.

The line charts illustrate the completion times added the noises in 10 running times. The line chart in Figure 9 presents the results of the completion times in the GA. The line chart in Figure 10 shows the results of the (1+1) EA.

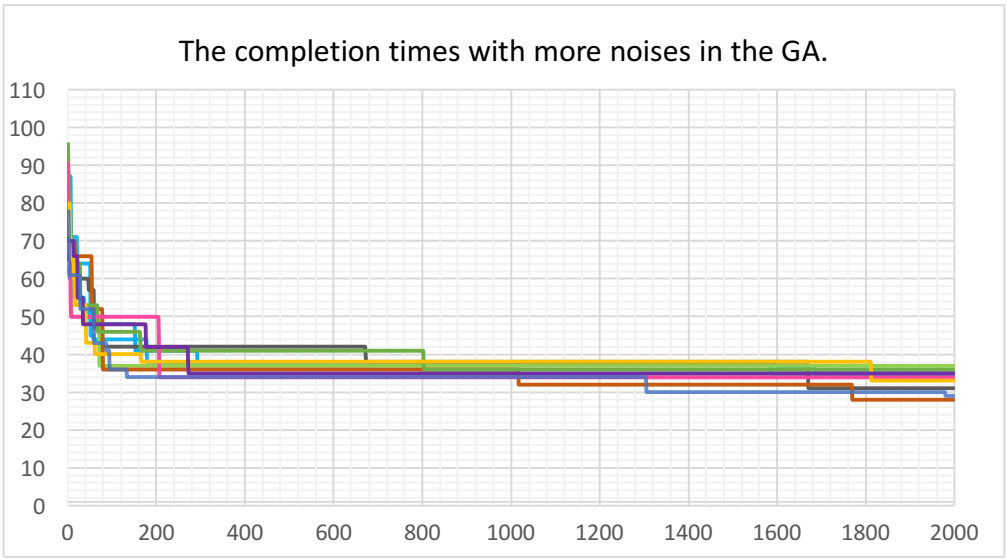


Figure 9. The results of the completion times with more noises in the GA.

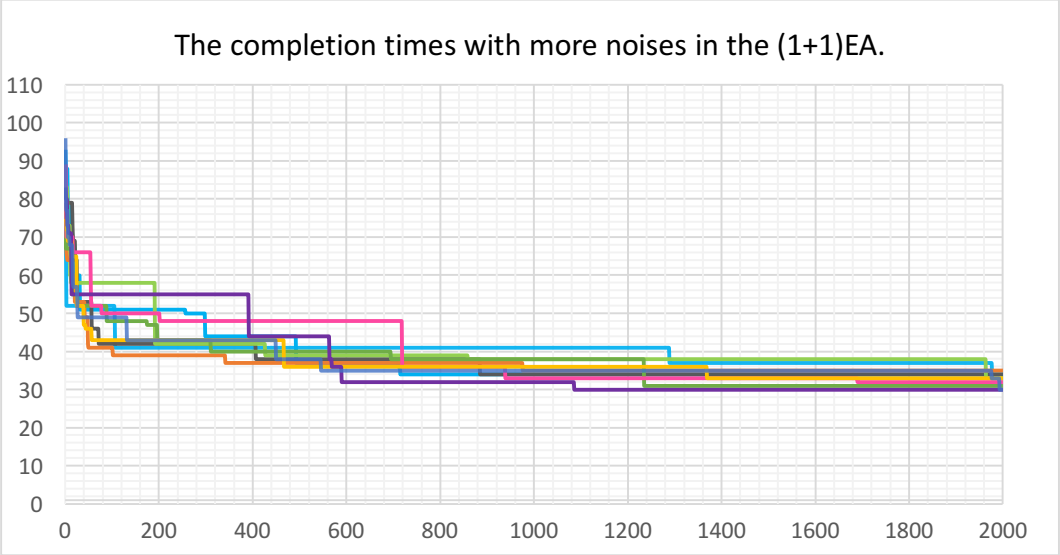
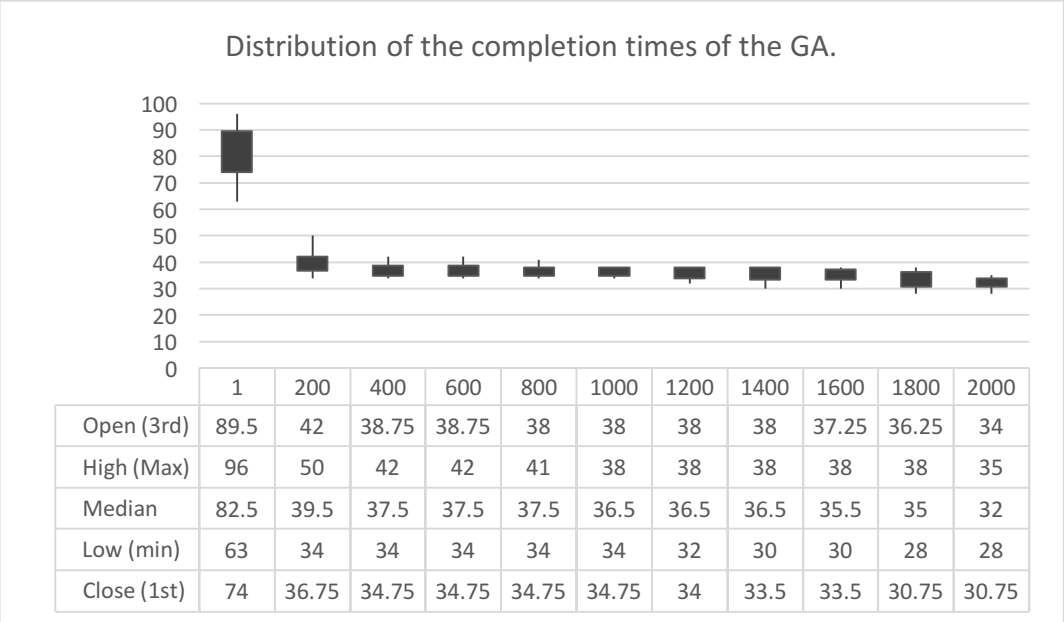


Figure 10. The results of the completion times with more noises in the (1+1) EA.

In Figure 9, the completion times of the GA decrease rapidly, then after 400 iterations, the completion times remain at 35 approximately. Some results reach down after 1000 iterations and reach down under 30 in 2000 iterations. In Figure 10, the completion times of the (1+1) EA decrease dramatically. The results of the completion times quite distribute between 0 and 700 iterations. The completion times is lower than 50 in 400 iterations. In addition, after 1400 iterations, the results remain until the end.

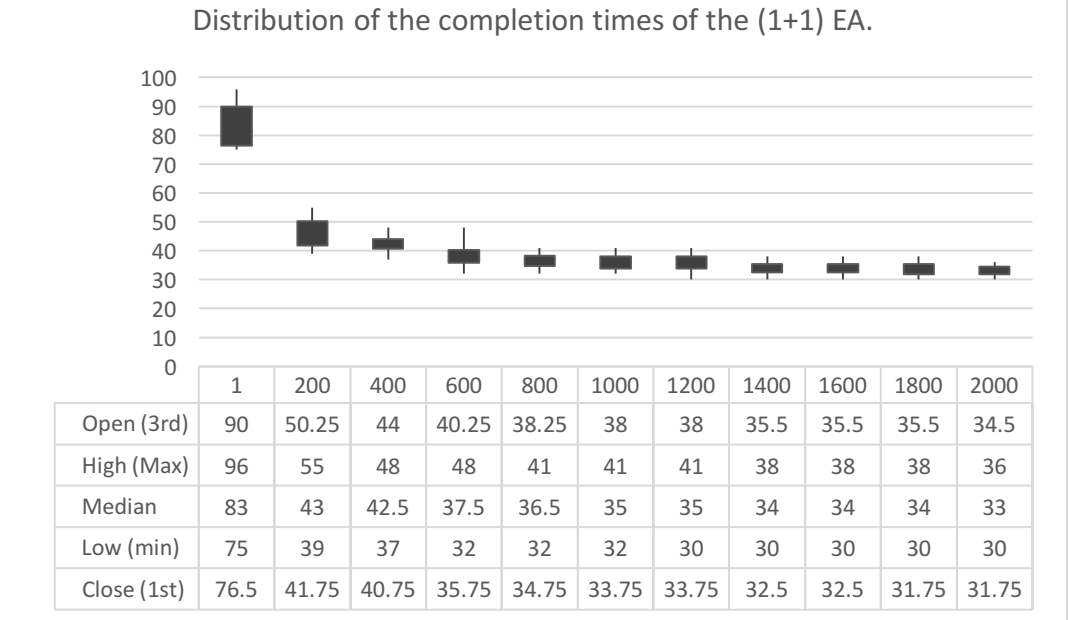
Overall, although we add more values of the noises to the completion times in both programs, the completion times of the project plans can go down nearly previous cases (small noise). The noise can only affect the completion times of the project plans at the beginning period.

Furthermore, the results of the completion times with more noises of the project plans in 10 running times illustrate in the boxplots. The boxplots distribute the data of the different completion times with more noises with 2000 iterations. The boxplot in Figure 11 is the results of the GA in 10 running times. The results of the (1+1) EA also present in Figure 12. The boxplots present some specific data of the completion times such as medians, lowest, and highest of the completion times in every 200 iterations.



	1	200	400	600	800	1000	1200	1400	1600	1800	2000
Open (3rd)	89.5	42	38.75	38.75	38	38	38	38	37.25	36.25	34
High (Max)	96	50	42	42	41	38	38	38	38	38	35
Median	82.5	39.5	37.5	37.5	37.5	36.5	36.5	36.5	35.5	35	32
Low (min)	63	34	34	34	34	34	32	30	30	28	28
Close (1st)	74	36.75	34.75	34.75	34.75	34.75	34	33.5	33.5	30.75	30.75

Figure 11. Distribution of the completion times of the GA in 10 running times.

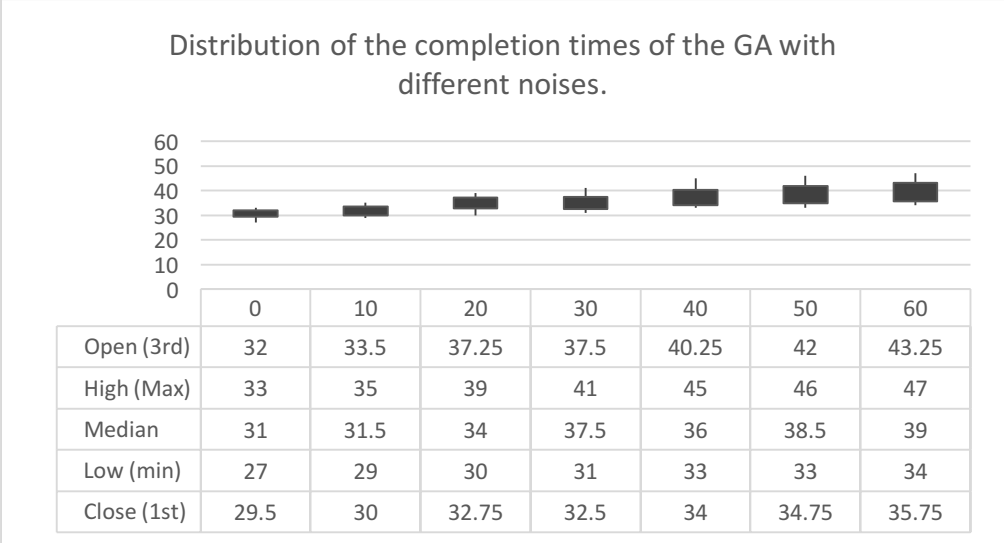


	1	200	400	600	800	1000	1200	1400	1600	1800	2000
Open (3rd)	90	50.25	44	40.25	38.25	38	38	35.5	35.5	35.5	34.5
High (Max)	96	55	48	48	41	41	41	38	38	38	36
Median	83	43	42.5	37.5	36.5	35	35	34	34	34	33
Low (min)	75	39	37	32	32	32	30	30	30	30	30
Close (1st)	76.5	41.75	40.75	35.75	34.75	33.75	33.75	32.5	32.5	31.75	31.75

Figure 12. Distribution of the completion times of the (1+1) EA in 10 running times.

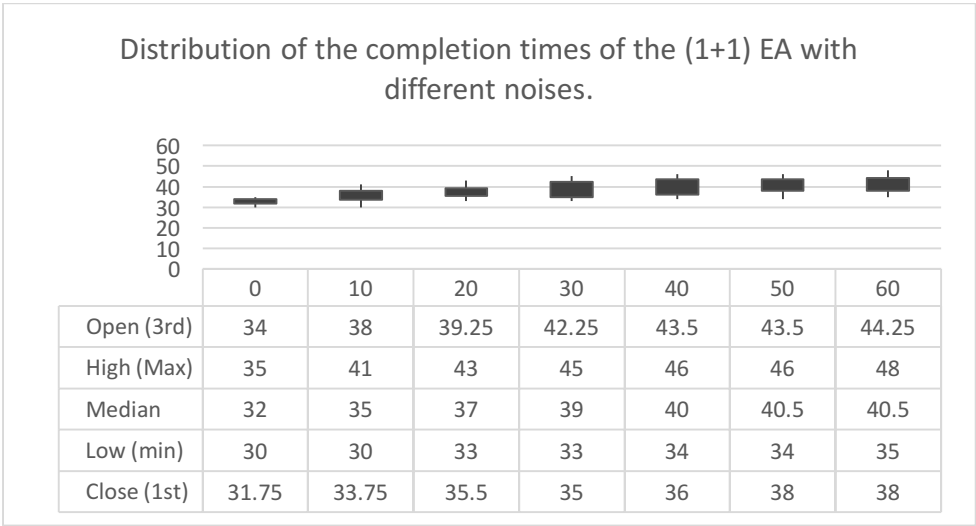
In Figure 11, the GA in the first iteration shows the median of the completion time at 82.5. At 200 iterations, the median of the completion times declines to 39.5 and then sinks gradually to 34.5 in 2000 iterations. In the same way, the (1+1) EA also reach down. The median of the completion time of the (1+1) EA in Figure 12 is 83. The median of the completion time of the (1+1) EA after 400 iterations is lower than 40 and then it drops to 33 in 2000 iterations.

Furthermore, we try to add the number of noises as following: 0, 10, 20, 30, 40, 50, and 60. The programs run in 10 times. The boxplot in Figure 13 illustrates the results of the completion times after 1000 iterations of the GA. The boxplot in Figure 14 also show the results of the completion times after 1000 iterations of the (1+1) EA.



	0	10	20	30	40	50	60
Open (3rd)	32	33.5	37.25	37.5	40.25	42	43.25
High (Max)	33	35	39	41	45	46	47
Median	31	31.5	34	37.5	36	38.5	39
Low (min)	27	29	30	31	33	33	34
Close (1st)	29.5	30	32.75	32.5	34	34.75	35.75

Figure 13. Distribution of the completion times of the GA with different noises.



	0	10	20	30	40	50	60
Open (3rd)	34	38	39.25	42.25	43.5	43.5	44.25
High (Max)	35	41	43	45	46	46	48
Median	32	35	37	39	40	40.5	40.5
Low (min)	30	30	33	33	34	34	35
Close (1st)	31.75	33.75	35.5	35	36	38	38

Figure 14. Distribution of the completion times of the (1+1) EA with different noises.

Overall, it can conclude that the project plans of two programs are robustness because the noises which are a small or large number do not impact the completion times of the project plans too much. In addition, the completion time of some project plans in the GA and (1+1) EA can drop to 28 and 30 respectively.

Experiment 3: trying to change the duration times of the sample project plan in the GA.

We discuss about the effects of changing resources of the project plan in the GA. If the duration times of some work packages are changed, the completion times will definitely change. We consider the completion times when the duration times are increased or decreased. The line graph in Figure 16 shows the results of increasing and decreasing the duration times. The line graph displays the three different completion times as following:

1. The original duration times of the sample project plan.
2. Increasing the duration times of work packages.
3. Decreasing the duration times of work packages.

The changes of duration times of work packages are shown in Figure 15.

	WP1	WP2	WP3	WP4	WP5	WP6
Duration of the sample plan	3	5	9	6	6	3
Increase duration times	10	12	12	10	10	8
Decrease duration times	3	3	5	5	5	3

Figure 15. The changes of the duration times of the project plan.

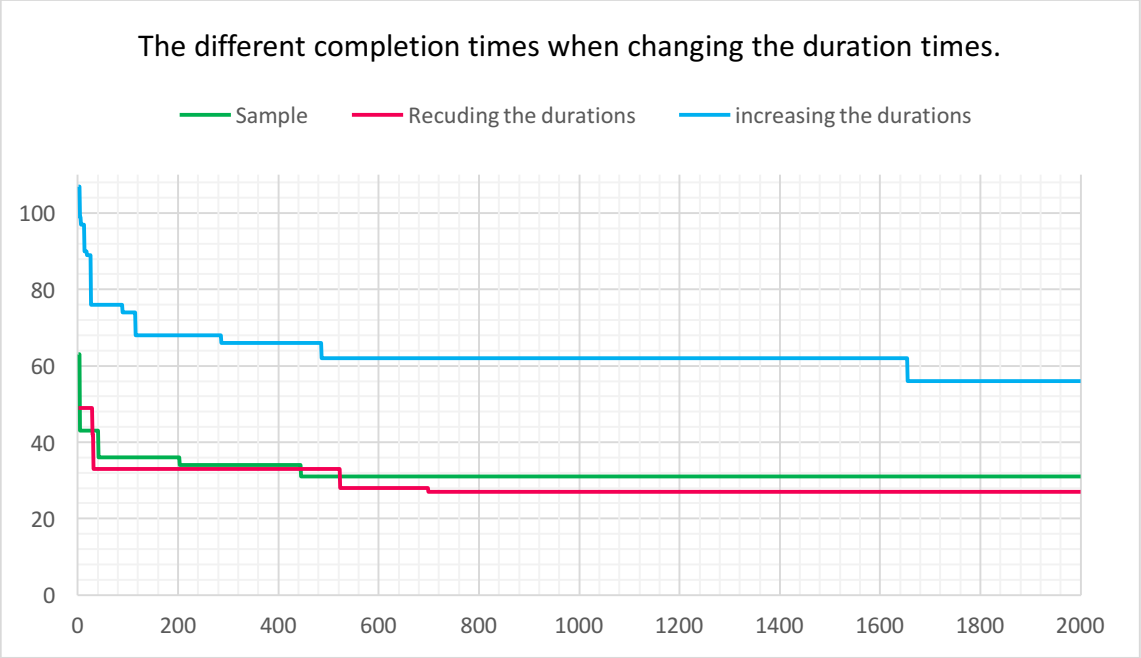


Figure 16. The different completion times in the GA when changing the duration times.

The line graph in Figure 16 illustrates that the changing durations of work packages impact to the completion times of the project plans in the GA. It can be note that the GA works to minimise the completion times. When we increase more duration times, the duration times of some work packages impact to increase the completion times of the project plans. In the first iteration, the fitness value reach more than 100. In the other hand, the duration times of work packages are reduced, the completion times also go down as well. Hence, the changes of the duration times of work packages influence the completion times of the project plan.

Experiment 4: trying to change work packages of the sample project plan in the GA.

Moreover, we also explore about the impacts of changing some resources of the project plan. If work packages of the project plans are changed, how to affect the completion times of the project plans. We discuss the completion times when changing work packages. The line graph in Figure 17 shows the three different results of the completion times of the project plans as following:

1. The original resources of the sample project plan have 6 work packages.
2. Adding more work packages (i.e. add 15 work packages), and as shown in Figure 17.
3. Removing work packages (i.e. remove two work packages), and as shown in Figure 18.

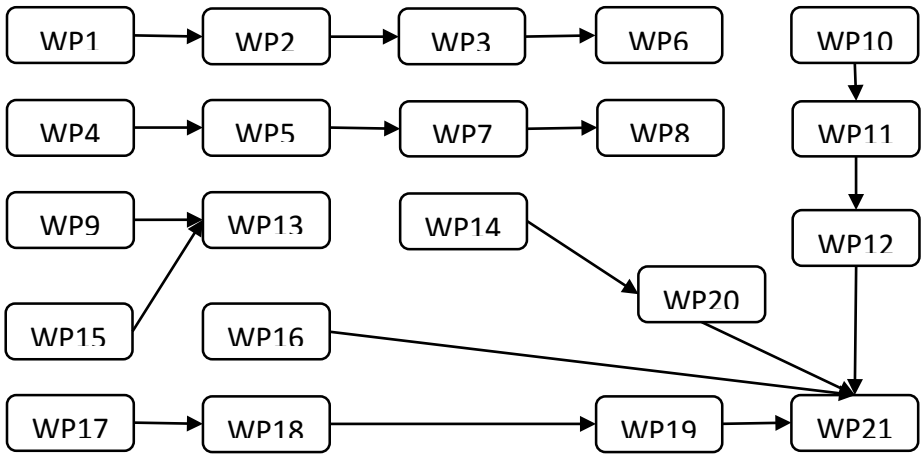


Figure 17. Add work packages to twenty-one work packages.

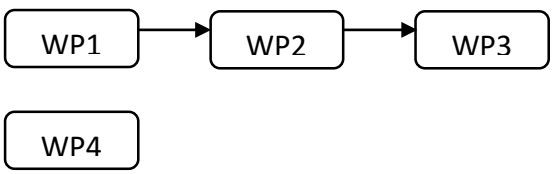


Figure 18. Remove work packages to four work packages.

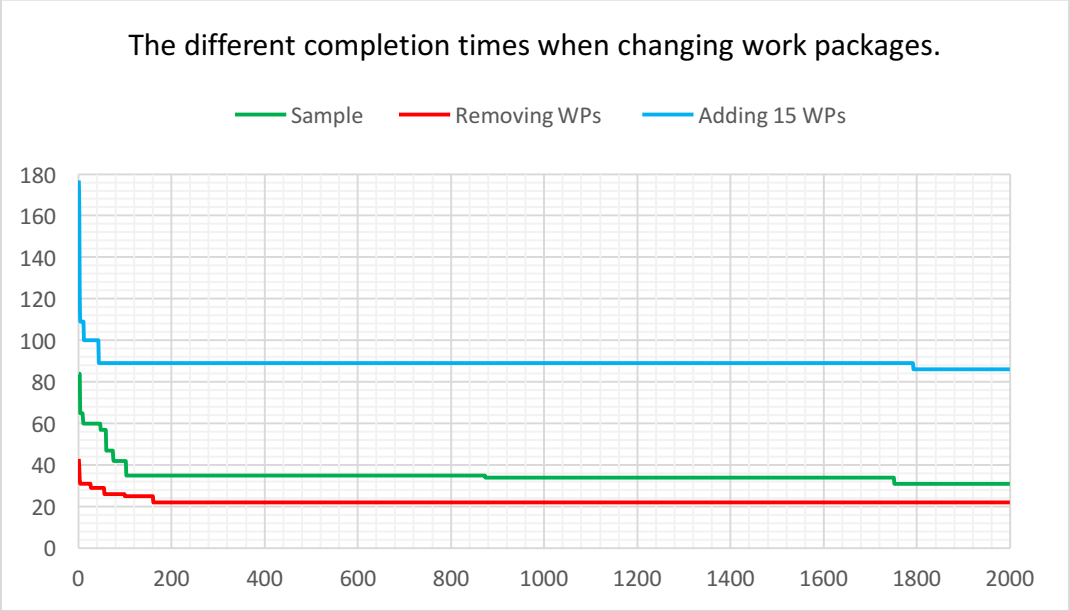


Figure 19. The different completion times in the GA when changing some work packages.

The line graph in Figure 19 displays the comparison of the completion times of the project plans of the GA which remove or add more work packages. When we add some work packages, the highest fitness value is 177 and the lowest fitness value is 86. The fitness value of the completion times of the project plans which add fifteen work packages decline to 86 days in 2000 iterations. However, when we remove two work packages, the fitness values of the completion times can be completely lower than the fitness values of the sample plan. The fitness value of the completion time in first iteration is 43 and then reach down to 22 in 2000 iterations.

Experiment 5: trying to change the dependencies of the sample project plan in the GA.

Furthermore, in this experiment, we add more dependencies in the sample project plan. The line graph illustrates the different completion times of the project plan that have changing the dependencies. The line graph presents the three different completion times as following:

1. The original resources of the sample project plan.
2. adding dependencies in work packages (i.e. 8 dependencies).
3. Removing all dependencies (i.e. no dependency).

The dependencies and work packages are presented in Figure 20.

The original dependencies = {(WP1→WP2), (WP2→WP3), (WP3→WP6), (WP4→WP5)}.

Adding 8 dependencies = {(WP1→WP3), (WP1→WP4), (WP1→WP5) (WP2→WP5), (WP3→WP5), (WP4→WP6), (WP5→WP6), (WP6→WP6)}.

For example, there are 12 dependencies of the sample project plan. We consider that the dependencies of the project plan may affect the completion times.

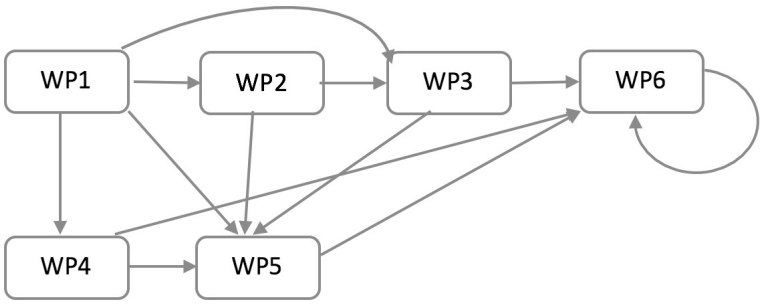


Figure 20. The dependencies and work packages of the sample project plan.

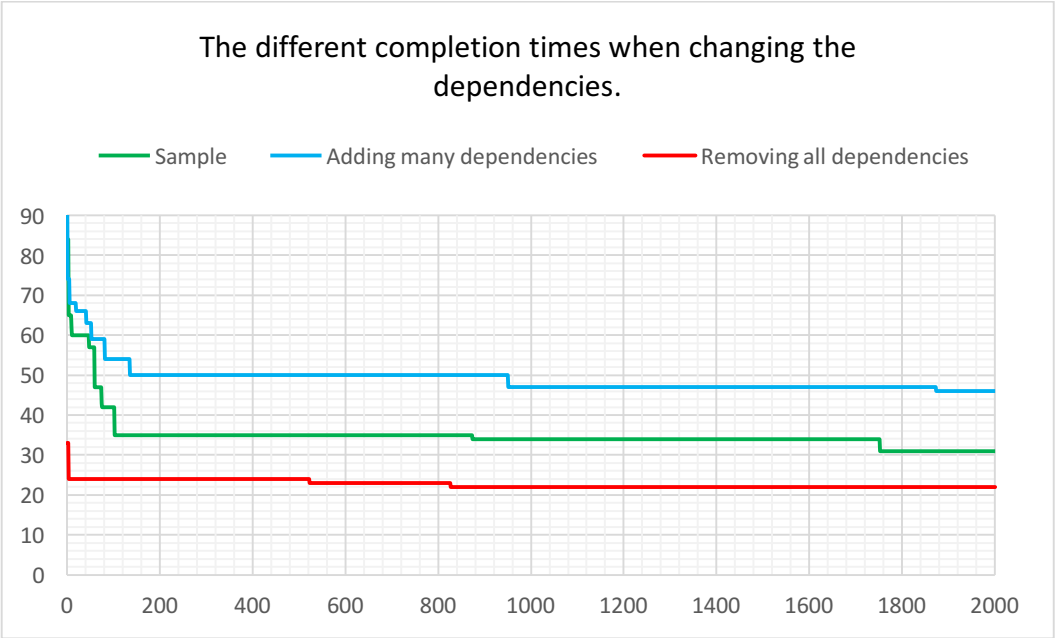


Figure 21. The different completion times in the GA when changing the dependencies

The line chart in Figure 21 illustrates the different completion times of the project plans. When we add many dependencies above, the GA try to minimise the completion times of the project plan with various dependencies. The lowest fitness value of the completion time of adding dependencies is at 40 in 2000 iterations. However, for non-dependencies, the fitness

value of the completion times can start lower than 40 at first iteration. The fitness value at 2000 iterations falls about 22.

Getting back to the details in experiment 1, the GA and (1+1) EA show the minimisation the completion times of the project plans in experiment 1. In experiment 2, the results of the fitness values in the GA and (1+1) EA present about robustness when unexpected resources occur in the project plans. It should be noticed that the GA minimise the completion times faster than the (1+1) EA. In addition, the project plans in the GA should be more robust than the (1+1) EA. Furthermore, experiment 3, experiment 4 and experiment 5 show that when we add or remove duration times, work packages, and dependencies, it should be affect the fitness values of the completion times of the project plans.

Therefore, it can be clearly observed that the increasing or decreasing results of the completion times of the project plans depend on the duration times, the number of work packages and dependencies. If the number of these factors is a large number, the fitness values of the completion times will certainly rise. On the other hand, if the number of these factors are removed to a small number, the results of the completion times will drop as well.