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Optimization of Optical Distribution Point Device Placement on Fiber Optic Cable Networks to Homes

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Abstract: Competition in telecommunications technology places demands on companies to always innovate to release the latest services. Currently, the issue of optical distribution point (ODP) infrastructure has become important in fiber to the home (FTTH) network access. This research aims to optimize the placement path for ODP devices on PT BCV's FTTH network using a traveling salesman problem (TSP) scheme with a hybrid genetic algorithm approach, testing is carried out using Matlab software. From the results obtained in this study, it was concluded that the hybrid genetic algorithm parameters for a population size of 100 with a number of iterations of 2000 by comparing the combination of cross probability parameters of (0.25), (0.5), and (1) and mutation probability of (0.050), (0.025) and (0.005) produces the best fitness value in the combination of Pcrossover = 0.25 and Pmutation = 0.005 and the worst fitness value in the combination of Pcrossover = 1.00 and Pmutation = 0.025. Therefore, researchers recommend a combination of genetic algorithm hybrid parameters with a combination of Pcrossover = 0.25 and Pmutation = 0.005 with a population of 100 and with a number of iterations of 2000.

Keywords: Genetic Algorithm Parameters, Hybrid Genetic Algorithm, Optical Distribution Point, Optimization, Traveling Salesman Problem.

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1. Introduction

Progress in technological development, especially in telecommunications, brings many benefits to every society. Communication is a very important need for society so the demand for communication technology is increasing [1]. The need for Internet use is increasing, so is the increase in internet service providers operating. Technological advances require companies to be able to always innovate to provide the latest services in order to survive the many business competitors [2]. The need for tripleplay growth, namely data, voice and video services, is very rapid, so stable and real time services require maximum speed for transferring data over the internet network [3]. A fiber optic cable network known as the Fiber to the Home (FTTH) network is available and functions to provide internet services at the same time [4]. FTTH deployment refers to optical fiber from the central office directly to the customer's home [1].

The Company's development of the innovation process began in 2018, which was carried out by PT BCV, namely by developing services into television and internet by implementing an FTTH network. The process of delivering various digital information or tripleplay effectively up to 2.5 Gbps (gigabit per second) over longer distances [3]. With a network architecture consisting of optical line termination leading to fiber termination management then going to the optical distribution cabinet then after that going to the optical distribution point then going to the rosette and ending at optical network termination [5]. Another important role in internet network installation is that the optical distribution point (ODP) functions as a place to connect fiber optic cables with a single mode fiber optic network connection [6]. ODP infrastructure is currently the main problem in FTTH network access, so the process based on customer demand is no longer important as technology develops because the development of ODP infrastructure is no longer dependent on customer demand [7]. The ODP infrastructure process using a manual placement process without a systematic method can have an impact on increasing the attenuation value of optical fiber based on cable length and cause cable distribution to become irregular [8]. The optimization process in innovation is a requirement that companies need to be able to maximize the resources needed [9].

This research aims to overcome the optimization problem of the ODP device placement route with customer data that obtained the best response in Kampung Belian, Batam City. The placement of the equipment is based on the minutes of recapitulation of the use of electricity poles from the State Electricity Company in Batam City, namely No. 00123.BA/REN.05.03/SMMULSER/2021. Optimizing the placement of ODP devices on the PT BCV FTTH network is carried out using the Traveling Salesman Problem (TSP) scheme based on the traveling salesman principle by searching for the shortest and most optimal travel path to be taken from the initial point of departure to the final point so that a special algorithm is needed that can optimize the path. Journey [10]. Therefore, research is needed to find the best ODP device placement route.

2. Literature Review

2.1. Fiber Optic Technology

Optical fibers is thin pieces of pure glass with a very small diameter. The principle used in optical fibers is perfect reflection by making the two refractive indices of the core and cladding different, so that light can be reflected and propagate within it [11]. Optical fibers have attenuation of less than 20 decibels (dB)/km, if the absorption process loses light due to dirt in the optical fiber [12]. The structure consists of the outermost part, namely the coating, cladding, or tube and the core is on the inside [13]. Fiber optic cables have 12 cable tubes in one large cable, in 1 cable tube there are 12 cable cores consisting of 12 different colors, with a diameter of approximately 120 µm and 2 types of models, namely single and multimode models. Single model diameter between 8.3-10 µm and multimode diameter 50-100 µm. The wavelength of the single model is 1310-1550nm and the multimode is 850-1300nm [14]. One example of the current application of fiber optic technology is in FTTH.

2.2. Fiber to the Home

FTTH is a series of fiber optic networks from the provider's center or head office to the customer's home as a transmission medium which has three services in one infrastructure, namely internet access, telephone network and video. The advantage is that it can reduce operating costs and can provide better service to customers [15]. The distance between the service centers, namely the head office, and the customer can be a maximum of 20 km. The central office contains devices such as Optical Line

Terminal (OLT) and Fiber Termination Management (FTM) which function as cable terminations from the OLT. Apart from that, there are several important devices that function to distribute signals via fiber optics to customers [14].

1. FTTH Attenuation
   FTTH networks really need attenuation calculations to avoid interference from the transmission media so that there is minimum and maximum attenuation. Minimum attenuation is 13 dB and maximum attenuation is 25 dB. If the attenuation is more than 25 dB and less than 13 dB then there will be interference on the transmission path (Imamah, 2018).
2. Gigabit Capable Passive Optical Network (GPON)
   GPON is a technology based on fiber optics as a transport medium to customers. GPON is a technology that uses the G.984 or Fttx standard. Downstream security uses 128-bit encryption and transmits upstream and downstream data using Wavelength Division Multiplexing (WDM) technology via optical fiber [16]. The advantage of GPON is that it can offer bandwidth of up to 2.488 Gbps to customers without losing bandwidth.

2.3. Optimization

Optimization is a form of activity or business with the aim of obtaining the best results based on the requirements or rules given [17]. Optimization algorithms are generally widely used to solve engineering problems [18]. An algorithm is a sequence of logical stages in solving a problem that is arranged systematically and logically. The word “logical” is a key word in algorithms. The steps in the algorithm must be logical and must be able to be determined to be false or true [19]. In general, there are two algorithmic methods for solving optimization problems, namely as follows [20]:

1. Conventional (Deterministic) Method is a method that uses pure mathematical calculations. Several methods are used to solve optimization problems, namely the Djikstra Algorithm, the Floyd-Warshall Algorithm, and the Bellmanford Algorithm.
2. Heuristic/meta-Heuristic Method. Some algorithms from the heuristic/meta-heuristic method used in optimization problems are the Tabu Search Algorithm, Artificial Neural Networks, Ant Algorithms, Genetic Algorithms and others.

2.4. Travelling Salesman Problem

Traveling Salesman Problem (TSP) is a heuristic approach in finding a solution because TSP is known as a Nondeterministic Polynomial-Hard (NP-Hard) problem [21]. The main problem is how a traveling trader can arrange his travel route to visit a number of cities with the distance between one city and another being known so that the distance traveled is the minimum distance where the traveling trader can only visit the city exactly once [22]. The rules that the TSP has are that you must visit each city exactly once, no more or less, then all cities must be visited in one trip, then start and end in the same city [23]. The purpose of the TSP method is to use the shortest or closest travel distance so that it can have an impact on distribution costs incurred by the Company because the TSP method can solve distribution problems by finding savings in distance, travel time and total travel time [24].

2.5. Genetic Algorithms

Genetic algorithms are designed to solve difficult industrial problems in the process of solving problems with conventional methods [25]. The concept of a genetic algorithm is a computational science that solves a problem by finding a solution in a natural way. Genetic algorithms are known as evolutionary algorithm types because they are often implemented in complex problems such as optimization problems with very complex mathematical models with computing times that tend to be stable. The smallest arrangement of a genetic algorithm is the characters, symbols, or numbers of a problem [26].

The process of genetic algorithm evolution begins by selecting a solution set randomly, which is then described by a chromosome called a population. When the initial population does not reach a good solution, a process of crossbreeding and mutation is carried out. Crossbreeding is needed to get the best solution and combination of the current population into a new population, where the selection depends on the best value. Mutations are carried out for random displays that change an individual's chromosomes. The effect of mutations usually only affects a few genes [27]. Genetic algorithms in solving optimization problems have advantages over other algorithms, namely [14]:

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1. It does not use many mathematical requirements in completing the optimization process and can be applied to several types of objective functions with several limiting functions in both linear and non-linear forms, so it can speed up the calculation process.
2. The evolution operation is very effective for observing random global positions.
3. Has the flexibility to be implemented efficiently on certain problems.

Based on literature studies, most research only examines TSP problems to find the shortest route or distance and genetic algorithms are used to find fitness values and obtain good results [28]. Apart from that, the TSP path resulting from an algorithm with a heuristic approach is not necessarily the best path, so it is improved using an algorithm developed with a metaheuristic approach [29].

1. Chromosome Initialization, with initialization parameters in this study:
   - UkPop = Population size used
   - Pcrossover = Probability of crossing over, probability of crossing over on chromosomes
   - Pmutation = Mutation probability, percentage probability of the total number of genes
   - MaxG = Maximum generation, the maximum possible generation in the calculation
   - Number of Genes = Number of genes represents the number of ODP points
2. Evaluation, namely the fitness value is obtained by processing chromosomes containing genes repeatedly over several generations and it is hoped that in each generation a chromosome will emerge with a better value than the previous generation. If the best fitness value is found then we have found a solution to this problem.
3. Selection, namely the process of screening candidates for the new generation. Good parents can produce good children. The higher a generation's fitness score, the more likely they are to be selected. The selection methods used are roulette wheel selection, elitism and steady state.
   - Roulette wheel selection method, where each chromosome forms a roulette circle in proportion to its fitness value [30]. This method is the simplest method and is often called stochastic sampling with replacement [31].
   - The elitism selection method is carried out to select individuals from the selected population and offspring to carry out the genetic process in the next generation [32]. A selection process that selects individuals with the highest fitness scores to enter the next generation. This method works optimally, so that all offspring and parents are collected in a holding pond and the population size with the best individual condition is eligible for the next generation [33]. The elitism method works by collecting all individuals in a bin population consisting of a set of parent individuals and a set of child individuals, after which elitist selection selects individuals with the best fitness value equal to the size of the original population.
   - Steady state, this method is not widely used in the selection process because it is done to maintain the best generation. In each generation, several chromosomes with the best fitness values are selected as the oldest. At the same time, the chromosome with the worst fitness score is replaced by new offspring, resulting in a large population that survives into the next generation.
4. Crossovers, choose the best fitness value in the mating pool in the previous section, then the chromosome with the best fitness value is used as the parent who will produce the child [34].
5. Mutation is a process that changes the composition of genes on chromosomes and plays a role in replacing genes lost from a population due to selection and crossing processes, allowing the reappearance of genes that were not present in the original population. The method used is mutation swapping, meaning that this technique starts by randomly selecting two gene positions and then swapping the two gene values at those positions [35].

The heuristic method chosen is a hybrid genetic algorithm which is a combination of methods into an evolved algorithm with the aim of providing an increase in the performance of the local search algorithm [36]. The genetic algorithm hybrid process takes place iteratively, where each iteration produces a new generation and will replace the previous generation which is considered a generation with poor quality. The hybrid stages of the genetic algorithm are as follows:

1. Generation of initial population, which begins by forming an initial population by representing chromosomes.
2. Calculating the fitness value is a stage in the process of evaluating each initial result that has been obtained using the split technique and obtaining the quality of each solution. In order for the

solution results to be better, local search is added at each evaluation stage because local search attempts to find or improve sub-routes for the solution that has been obtained.

3. The individual selection stage uses the roulette wheel's selection technique, namely as the stage for determining the parent. A large fitness value will have a high probability of being selected, then the selected parents will be cross-bred using the multiple point crossover technique, where the first parent is exchanged for the second parent and the result of the cross is called the child, then the child resulting from the cross is called the parent.
4. The selected parents undergo the mutation stage, namely the individual exchange of chromosome parts for each child that has been obtained from the crossing stage and will be mutated using the scramble mutation technique, namely the mutation process by selecting the positions of several genes at random, then the order of these genes will be exchanged randomly.
5. Mutations produce new individuals or offspring called offsprings. The offsprings that have been determined are then evaluated using the split technique and corrected with the local search algorithm.
6. Updating generations or populations (elitism) by replacing chromosomes that have the worst quality in the population with offspring that have better fitness values.
7. The process takes place iteratively, so that each stage will stop if the iteration meets the stopping condition and the solution produced after the process ends is called the chromosome or solution with the best fitness value.

3. Methodology

The research was conducted in Kampung Tua Belian which is in the Batam Center City area, Batam City, Riau Islands, where there are still locations where fiber optic lines have not been built. The route was chosen because it has a good level of marketing within 1 year. It is hoped that with the construction of this fiber optic line, all points at the locations that will be designed will allow the community to experience fast data communication services. Design will start from January 2022 to April 2022. Figure 1 shows the location of Kampung Tua Belian and Figure 2 shows the research flow diagram. There are two main supporting tools in this research, namely:

1. Software MATLAB R2016a, is software used to design FTTH access networks at each point using the TSP problem.
2. Google Earth, used to create points for placing devices that will be used in design and to obtain data in the form of coordinates (latitude and longtitude).

Figure 1. Location map of the FTTH network designed in Kampung Tua Belian

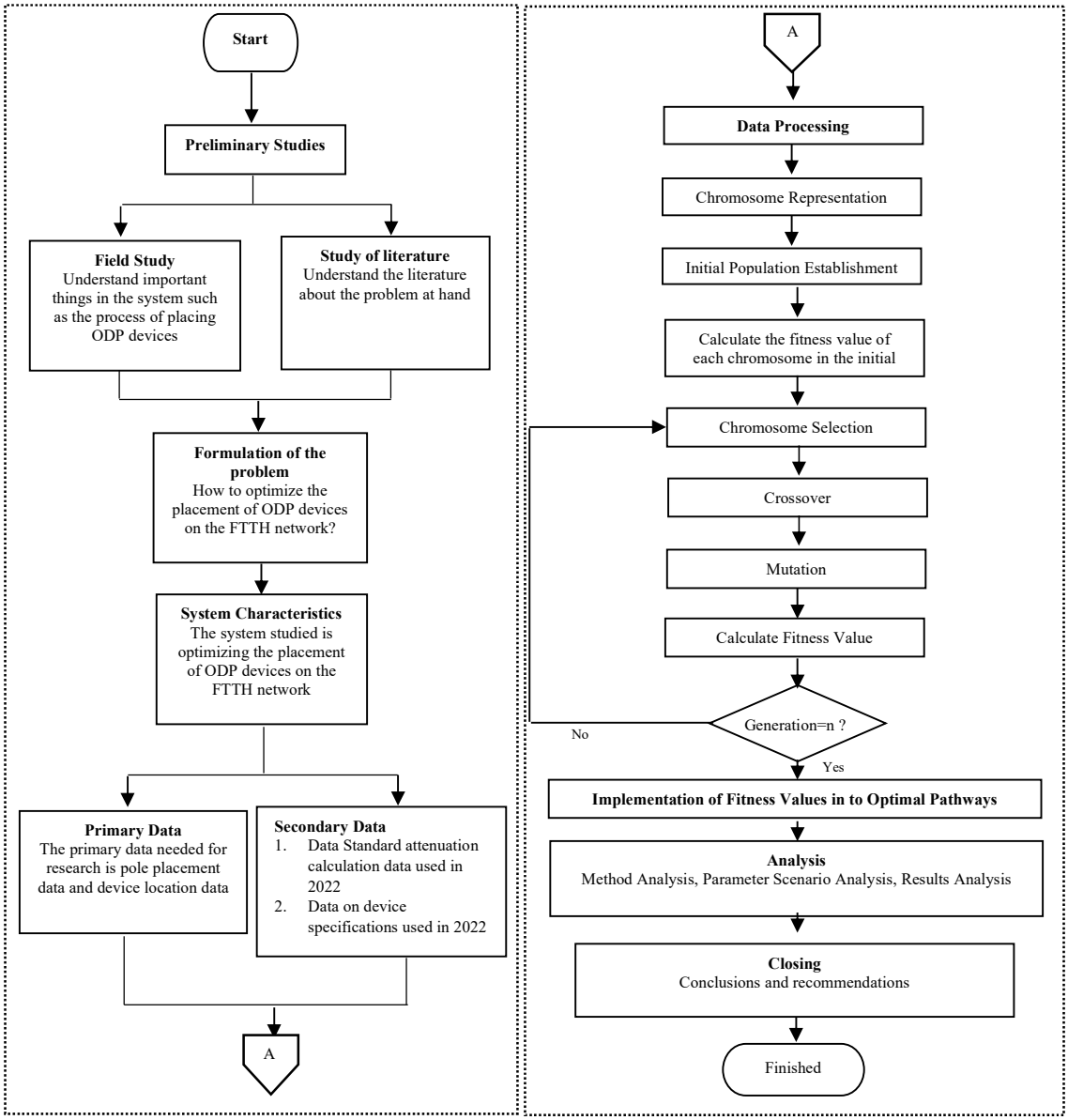

Figure 2. Flowchart Diagram

4. Finding and Discussion

There are six algorithm processes in representing TSP calculations for genetic algorithms and genetic algorithm hybrids shown in Figure 3 and Figure 4.

1. Population Initialization: The population of each chromosome contains genes that represent the sequence number of the ODP device point placement. The number of genes in each chromosome is equal to the number of ODP device points.
2. Individual Evaluation: The fitness value calculation implemented in this function is three variables, namely Chromosome, JumGen, and XYlocation. The XYlocation variable contains the coordinates of all ODP device points.
3. Fitness Value Scaling: To avoid the tendency to converge on the local optimum, a fitness value scaling process is carried out, so that fitness values are obtained that are in the interval [MaxF, MinF] so that new, better fitness values are obtained, which have high variance.
4. Method Selection: The selection used in this selection process is the roulette wheel method. The roulette-wheel function is implemented to obtain output in the form of Pindex, namely the index of the individual selected as a parent.

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5. Crossovers: The recombination process is carried out at the crossover stage. At this stage, pairs of parents are selected at random and the combination of genes from each parent is combined to produce a new child.
6. Mutation Process: After the recombination process, a mutation process is carried out. In this process, several randomly selected individuals will be mutated by changing the values of several of the individual's genes with random values.

Generation of the initial population is carried out by generating genes for each pole, namely 40 device placements in one population (chromosomes) and generating as many populations as are initialized in one generation. Population generation process in Matlab 2016a with initialization of the required parameters, namely:

1. UkPop used (10), (50), and (100).
2. Pcrossover used (0.25), (0.05), and (1).
3. Pmutations used (0.005), (0.025), and (0.05).
4. MaxG is the maximum generation in the calculations used, namely 2000 iterations.
5. Number of Genes is the number of genes in a chromosome which also states the number of locations, namely 40.

Hybrid genetic algorithm which is a combination of a local search algorithm into a genetic algorithm with the hope of improving the performance of the genetic algorithm. The parameter scenario analysis is determined with a population size of (100), a crossover probability of (0.25), (0.5), and (1) and a mutation probability of (0.050), (0.025) and (0.005) with a maximum generation of (number of iterations) is 2000. The genetic algorithm hybrid fitness value is shown in Table 1.

Table 1. Results of Hybrid Genetic Algorithm Fitness Values

UkPop	Pcrossover	Pmutation	Fitness Value	Time (seconds)
100	0.25	0.050	33.1614	82.69
		0.025	41.0041	82.90
		0.005	**45.4415**	**81.48**
	0.5	0.050	35.5717	79.47
		0.025	38.0033	78.98
		0.005	**45.3086**	**79.73**
	1	0.050	28.6457	89.93
		0.025	**37.8716**	**89.18**
		0.005	35.7155	65.99

Based on the results obtained in Table 1, it can be seen that with 2000 iterations the genetic algorithm tends to give good results and it can be seen that the best combination to get the highest fitness value is:

UkPop = 100, Pcrossover = 0.25 and Pmutation = 0.005 on the fitness value45.4415
UkPop = 100, Pcrossover = 0.50 and Pmutation = 0.005 on the fitness value45.3086
UkPop = 100, Pcrossover = 1.00 and Pmutation = 0.025 on the fitness value37.8716

Based on the results of this research, it can be seen that the combination of testing a population size of 100 with crossover probabilities of (0.25) and (0.5) obtained the highest fitness value at a mutation probability of 0.005. However, there is a difference with a population size of 100 and a crossover probability of 1, where the resulting high fitness value is at a mutation probability of 0.025.

A comparison of the fitness values of the hybrid genetic algorithm between the three combinations is shown in the test results graph in Figure 5, Figure 6, and Figure 7. Based on observations of the fitness values produced using a population of 100, it can be seen that the best fitness value is obtained from the combination of Pcrossover = 0.25 and Pmutation = 0.005, which is then followed by the combination of 0.50 and Pmutation = 0.005 on the same population size. With the same observations,

it can be seen that the combination of UkPop = 100, Pcrossover = 1.00 and Pmutation = 0.025 gives the worst fitness value.

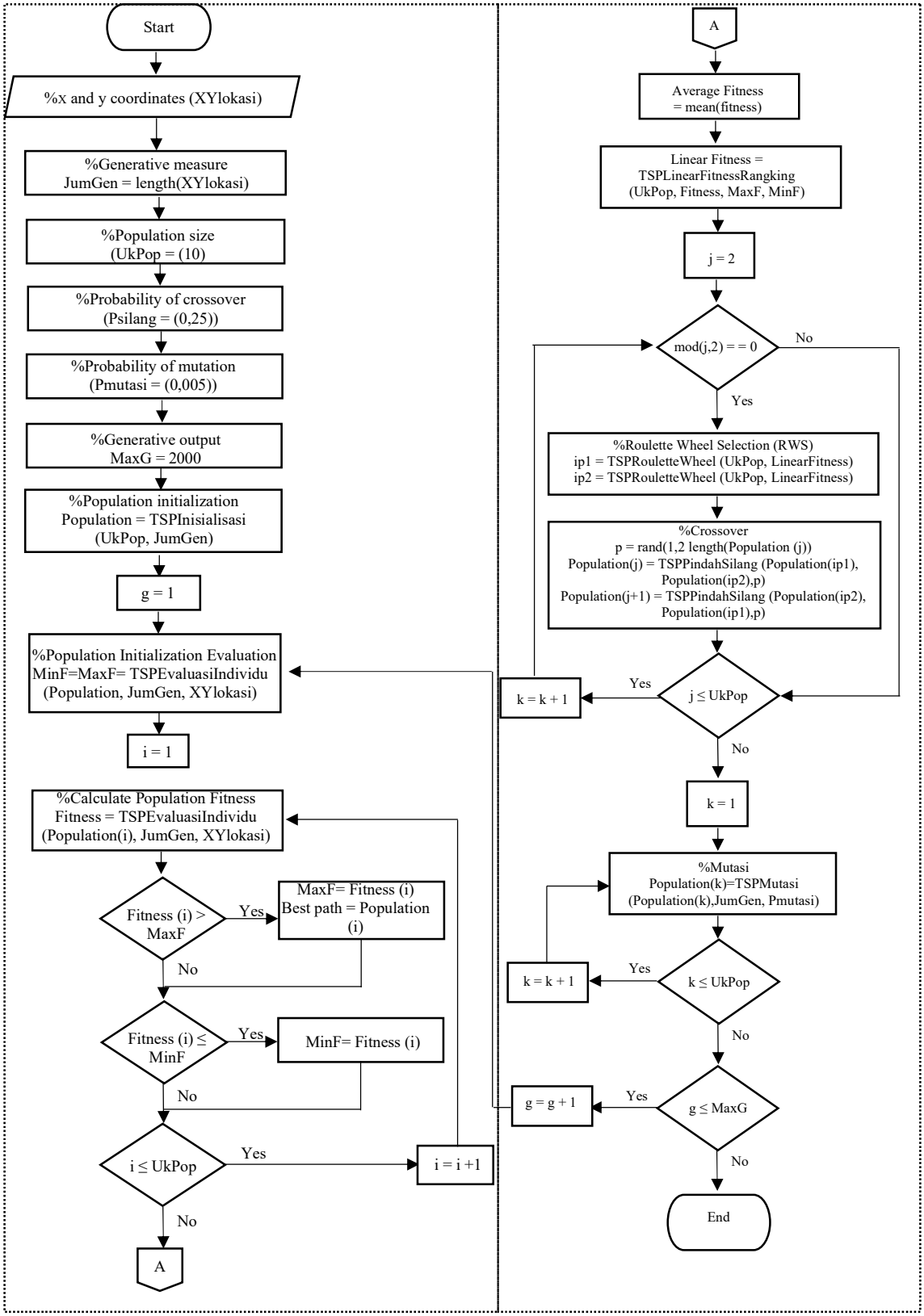

Figure 3. Conceptual Model of TSP and Genetic Algorithm

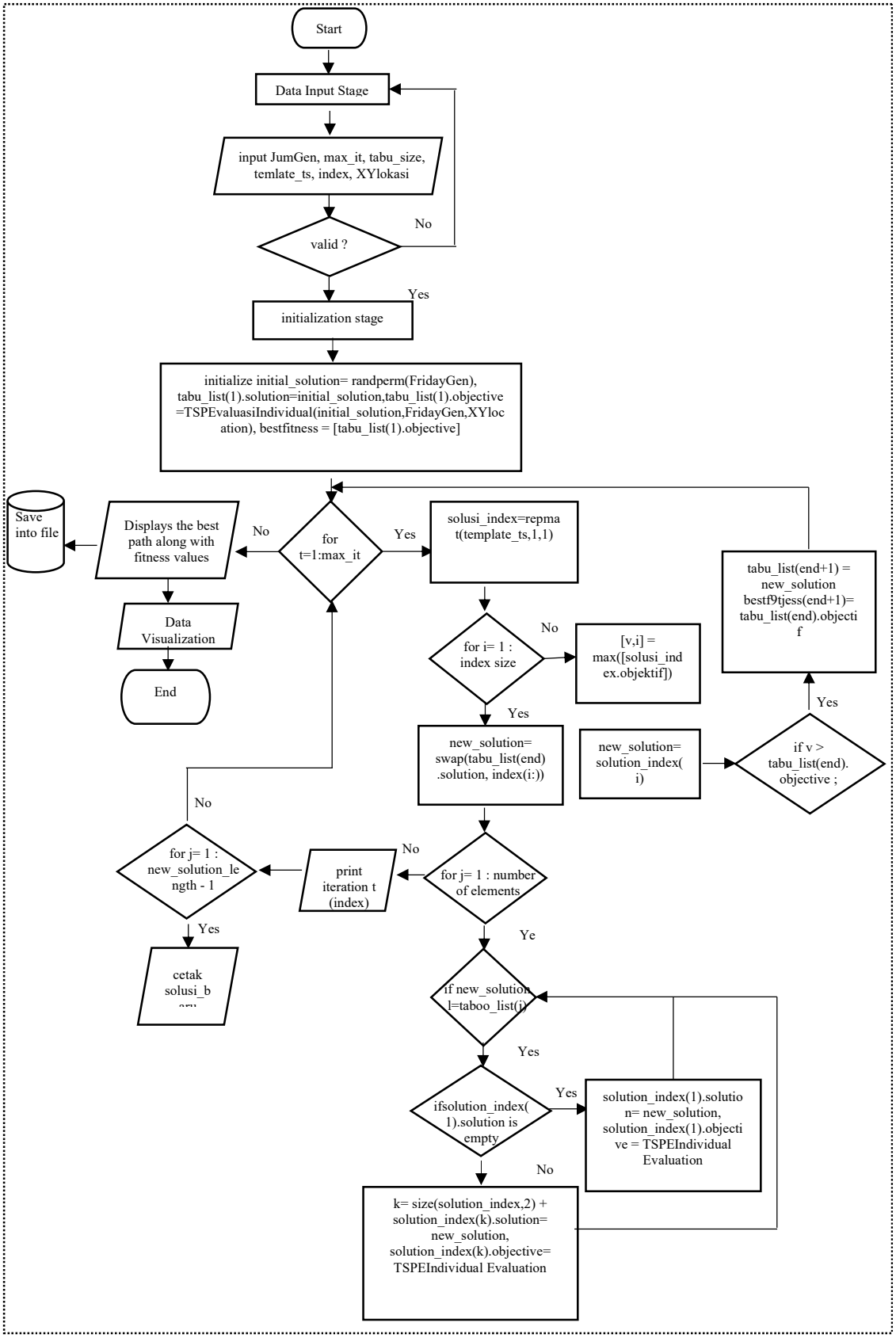

Figure 4. GA Hybrid Conceptual Model

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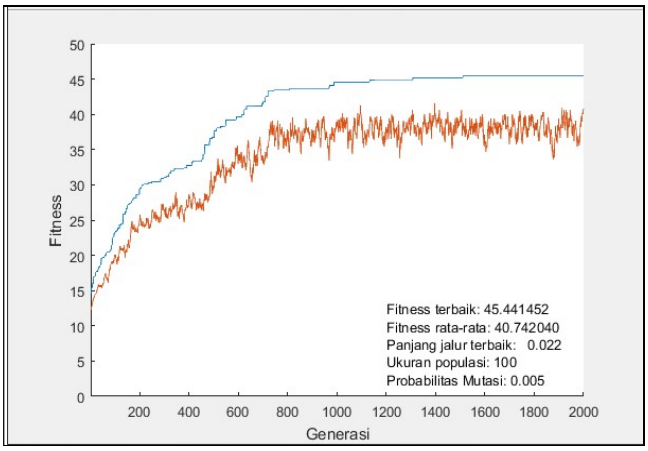

Figure 5. Graph of Pcrossover Program Testing 0.25 Pmutation 0.005

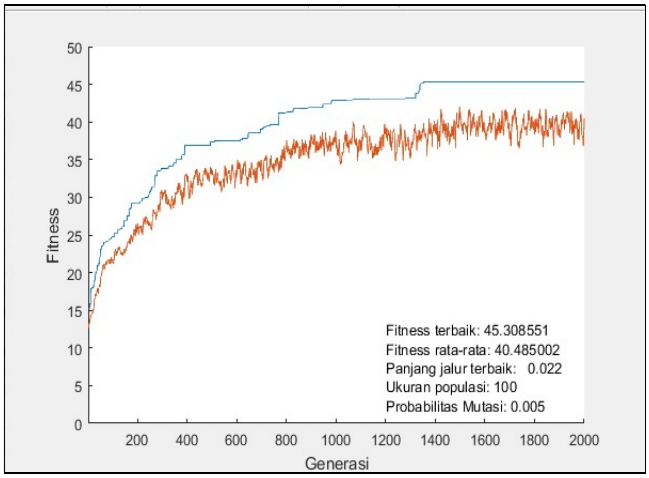

Figure 6. Graph of Pcrossover Program Testing 0.5 Pmutation 0.005

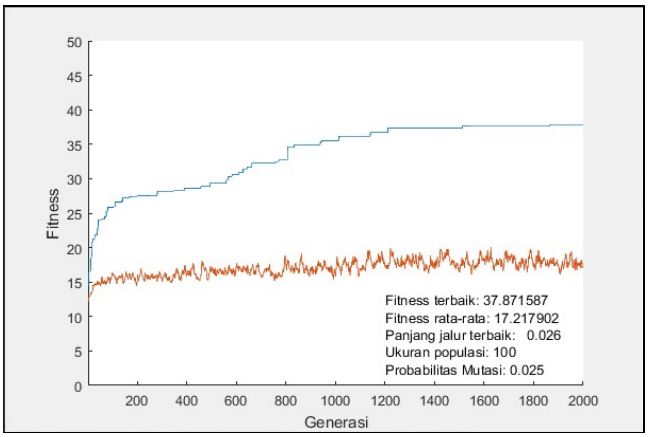

Figure 7. Graph of Pcrossover Program Testing 1 Pmutation 0.025

5. Conclusion

Based on the results obtained in this study, it was concluded that the hybrid parameters of the genetic algorithm for a population size of 100 with a number of iterations of 2000 by comparing the combination of cross probability parameters were (0.25), (0.5), and (1) and the mutation probability was (0.050), (0.025) and (0.005) yield:

- The best fitness value is the combination of Pcrossover = 0.25 and Pmutation = 0.005.
- The worst fitness value is the combination of Pcrossover = 1.00 and Pmutation = 0.025.

Therefore, researchers recommend a combination of genetic algorithm hybrid parameters with a combination of Pcrossover = 0.25 and Pmutation = 0.005 with a population of 100 and with a number of iterations of 2000.

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