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CHAPTER 10. IMPLEMENTATION OF GENETIC ALGORITHM TO COMPLETE TRANSPORTATION PROBLEMS OF INTERCITY BUS VEHICLES

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Abstract

The design and implementation of a software as a tool to solve the multiple criteria transportation model with fuzzy cost parameters has been carried out using genetic algorithms. This software is named TraFAG. The software design uses the Waterfall methodology, which consists of analysis, design, implementation and testing. The algorithm used is a genetic algorithm. This algorithm is based on genetic processes that exist in living things, namely the development of generations in a natural population, gradually following the principle of selection or who is strong who will survive. In the transportation system, the effect of congestion on transportation means results in uncertainty in part or all of the coefficients on objective functions, such as transportation costs or delivery times, which become uncertain. A way to deal with uncertainty in making these decisions using fuzzy principles. The fuzzy cost parameter in TraFAG uses the Triangular Fuzzy Number (TFN). In multiple criteria optimization, the determination of the optimal value uses the Pareto solution. The Pareto solution is determined based on ordered fuzzy objective values. Comparison and sorting of fuzzy numbers, using integral values. The TraFAG software is implemented in the Borland Delphi version 3.0 programming language environment. which is the development of the Pascal language for the Window-based programming environment. The solution of multiple criteria transportation problems can be solved by a heuristic approach using genetic algorithms. Analysis of the results of the program shows that the processing time in the test case will be directly proportional to the product of the number of source and destination depots with a correlation coefficient of 0.89. The analysis also shows that the number of population is linearly proportional to each test case to the processing time with a correlation coefficient of 0.99. The parameter α indicates the degree of optimism will affect the result of the integral value linearly. The higher the alpha value, the greater the transportation costs. The alpha that should be chosen is a value of 0.5, which is a moderate value so it is in a safe condition. The alpha which yields the minimum cost for test case 2 to test case 6 is 0.1. The greater the population, the smaller the fitness function. The greater the number of generations, the lower the transportation costs. The results obtained are relatively stable on average in the generation 300 and above. The crossover probability affects the fitness function. In cases 13 and 15, the crossover probability that results in the minimum fitness function value is 0.1. The mutation probability has a lot of influence on the fitness function. In case 2 it causes a stable mutation probability with a fitness value of 48.35.

Keywords: Fuzzy, Genetic Algorithm, Transportation Problems, Waterfall.

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Title
Abstract

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Implementation of Genetic Algorithm to Complete Transportation Problems of Intercity Bus Vehicles

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Chapter 10

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Preliminaries

Chapter 10 Summary

Implementation and design a software as a tool to solve the type of bus transportation between cities using a genetic algorithm. Systems development methods the software design uses the waterfall methodology, which consists of analysis, design, implementation and testing. The algorithm used is a genetic algorithm. The stages that occur in genetic algorithms are based on genetic processes contained in the population of living things, namely the natural population in the development of generations using the principle of selection.

Method in the transportation system, the effect of congestion on transportation means results in uncertainty in part or all of the coefficients on objective functions, such as transportation costs or delivery times which become uncertain. A way to deal with uncertainty in making these decisions using fuzzy principles. The fuzzy cost parameter for bus transportation between cities uses the triangular fuzzy number. In multiple criteria optimization, determining the optimal value uses the pareto solution. The pareto solution is determined based on ordered fuzzy objective values. Comparison and sorting of fuzzy numbers, using integral values. This bus transportation between cities software is implemented in the borland delphi version 7.0 programming language environment which is a development of the pascal language for window-based programming environments.

The way to solve problems for bus transportation between cities can use a heuristic approach, namely the genetic algorithm. Based on the results of the program analysis that has been carried out, it proves that the number of source and destination depots in a product is directly proportional to the processing time, the result of the correlation coefficient is 0.87. Based on the results of other analyzes proving, each test case to processing time is directly proportional to the number of population, while the results of the correlation coefficient are 0.95. The parameter α indicates the degree of optimism will affect the result of the integral value linearly. The higher the alpha value, the greater the transportation costs. The alpha that should be chosen is a value of 0.5, which is a moderate value so it is in a safe condition. The alpha which yields the minimum cost for test case 2 to test case 5 is 0.17. The greater the population, the smaller the fitness function. The greater the number of generations, the lower the transportation costs. The results obtained are relatively stable on average in the generation 300 and above. The crossover probability affects the fitness function. In cases 11 and 14, the crossover probability that results in the minimum fitness function value is 0.17. The mutation probability has a lot of influence on the fitness function. In case 2 it causes a stable mutation probability with a fitness value of 47.95.

10.1 Introduction

Genetic Algorithms "Genetic Algorithm (GA) is a branch of evolutionary algorithms which is an adaptive method commonly used to solve a value search in an optimization [19]". "This algorithm is based on a genetic process that exists in living things, namely the development of generations in a natural population, gradually following the principle of selection or who is the strongest who will survive. By imitating this process, GA can be used to find solutions to problems in the real world [4] ". "Founder of the basic principles and creator of GA is [14]". GA uses the direct analogy of natural habits, namely natural solutions. In the genetic algorithm each individual can provide solutions to all problems that

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arise. The fitness value is used for individuals who are included in the genetic algorithm. And will be used to get the best value solution, in the problems that arise. The development of individual population cultures can use cross-breeding in a population. Individuals resulting from new cross-breeding are called offspring, with characteristics like their parents. Individuals who are not selected for breeding will automatically die in this population. So with this step of the process, a new generation of individuals will be born, who have the best characteristics in a population, these individuals will mix and be exchanged with other characteristics. By marrying as many individuals as possible, the more the best possibilities will be obtained. "The problem of transportation discusses the delivery of goods from several sources to a number of destinations [10]". Each source and destination has a supply and demand for a certain amount of commodity. The purpose of solving this problem is to allocate the supply of each source to meet demand. each destination in such a way as to minimize total transportation costs. Transportation problems can be divided according to the function of the destination and its limitations. According to its objective function, transportation problems can be separated between linear and nonlinear, and between single criteria and multiple criteria. According to its limits, transportation problems can be separated between solid and planar, and between equilibrium and unbalanced. "Genetic algorithms can be used to solve linear transportation problems [19]". The use of genetic algorithms is an example of constrains optimization problems that examines how these constraints are with genetic algorithms and shows the ability of a genetic algorithm that gives freedom to use any data structure on a problem together with its genetic operators. "Multiple criteria linear transport problems and solid and dual criteria planar transport problems can be solved using genetic algorithms [18]". Several multi-objective linear programming methods, especially for transportation problems, have been developed using a variety of conventional approaches, for the multi-objective case it is to produce an extreme point of non-domination in the decision space. By following this methodology, the use of genetic algorithms is intended to determine the set of non-dominating points. With this basic idea, genetic algorithms are a method that can be used to solve multi-objective optimization problems. With the multiple criteria approach, in addition to transportation costs, many other influencing factors such as delivery time, quantity of goods shipped and decreased production.

10.2 Research Purposes

The purpose of this research is because in the transportation system, the effect of congestion means of transportation results in uncertainty in part or all of the coefficients on objective functions, such as transportation costs or delivery time which cannot be known with certainty. "A way to deal with uncertainty in decision making uses the fuzzy principle [17])". With the fuzzy principle, a method of solving transportation problems will be developed with the addition of fuzzy transportation costs to handle uncertainty in the objective function parameters. The use of fuzzy numbers on transport of cost supply and demand resulted in the formation of fuzzy transportation problem [2].

10.3 Problem Limitation

Given the complexity of the fields and problems being studied, then limiting the problems is carried out. The problems that will be discussed in this study are limited to:

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a. Balanced condition, the number of commodities in stock at the source depot is the same as the number of commodities demanded at the destination depot. The unbalanced condition is not discussed.
b. Fuzzy transportation cost parameters use triangular fuzzy number.
c. The transportation problem discussed is planar, with the same transportation vehicles and unlimited capacity.
d. The cost of transporting goods from a source to a certain destination is linearly proportional to the number of units of goods shipped.

10.4 Terms in Genetic Algorithms

Many optimization problems are difficult to solve with deterministic optimization techniques. Researchers then mimic the evolutionary process or living things in an attempt to solve the problem. The transportation model is a linear program application that is used to get the optimum solution of distribution problems, especially the problem of minimizing transportation distribution costs [22]. This approach gave birth to an optimization technique called evolutionary algorithms. GA works to mimic a natural evaluation process. In evolution, the problem that must be faced by each species is adaptation to the environment which is complex and changes every time. By using a genetic algorithm, the preparation of a delivery schedule for goods from the city of origin to the destination city can be done optimally [9]. The application of genetic algorithms in solving nurse scheduling problems can meet all hard limits, and minimize violations of the predetermined soft limits, so that the predetermined scheduling can fulfill the predetermined rules [7].

Species that are able to adapt will continue to survive while those that are not able to adapt will disappear from the population. "Because GA has its roots in genetics and computer science, terms from both fields are widely used. These terms can be mentioned as follows [18] ":

a. Chromosome.
Chromosome are the repository of genetic information. In genetic algorithm in general strings are analogous to chromosomes.
b. Structure (genotype).
The genetic elements of an individual or group are called genotypes. In genetic algorithm, the structure is analogous to a genotype.
c. Parameter set (phenotype).
The interaction in the structure occurs because of the transformation process of genetic codes. The phenotype is a representation of the parameter set of the problem at hand. Code representation can be numeric or non-numeric.
d. Genes The elements that make up chromosomes are genes.
e. Alleles (feature value).
Allele is a group of genes that will appear alternately in the locus.
f. Locus (positioning).
Locus is the location of genes on a chromosome that will provide features to the allele. Each feature has an ordered position in the string.

10.5 General Structure of Genetic Algorithm

The genetic algorithm is a search technique, which is based on natural selection and natural genetic search mechanisms. The genetic algorithm will produce the optimal solution

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in each generation [8]. The genetic algorithm has a different mechanism from conventional search techniques. Genetic algorithm departs from a set of randomly generated solutions. The population is a group of individuals who will be processed together in one cycle of the evolutionary process [23]. Genetic algorithms in particular are applied as computer simulations, in which a population of abstract representations is called chromosomes, from which the candidate solutions are called individual solutions, this optimization problem will develop into a better solution [13].

Chromosome is a combination of genes to form certain values. Generation represents one evolutionary cycle or one iteration in a genetic algorithm. The evaluation function in genetic algorithms is a function, which provides an assessment of the chromosomes (fitness value), to be used as a reference in achieving the optimal value. This fitness value then becomes the weight value of a chromosome. The chromosomes selected with the best fitness value in the selection process will continue to the reproduction process.

The reproduction process is known as the crossover process, the chromosomes that are produced from this crossover process are continued to the mutation process. In the mutation process, a change of genes is not good, with good genes, the chromosomes from this mutation process will become a new generation (offspring) to form a new population. In each chromosome generation is evaluated based on the evaluation function. The new population experiences the same cycle as the previous population. The process continues until the nth generation to produce the expected generation.

Usually initialization is randomly generated. Reproduction in particular will carry out an evaluation process with two types of operators owned by GA, namely cross-exchange and mutation so that a new chromosome called offspring will be produced. It can be stated that in GA there are only 2 (two) main operations, namely:

a. Genetic operators: crossovers and mutations.
b. Evaluation operations.

10.6 Selection

Genetic surgery mimics the process of inheriting genes in the evaluation process to produce the best population offspring. The evaluation operation mimics Darwin's evolutionary process to produce new individuals from one population to the next.

10.7 Structure of Genetic Algorithm

General Algorithm (GA) is a search technique based on natural selection mechanisms and natural genetics. In contrast to conventional search techniques, GA departs from a set of randomly generated solutions. The set of solutions is called a population. Each individual in the population is called chromosomes which is a representation of a solution. A chromosome is represented by a series (string) of symbols and usually as a binary string, the chromosomes evolve in a continuous iteration process called generation. Each chromosome generation is evaluated based on an evaluation function. Chromosomes with a higher fitness value have a greater chance of being selected as parents in the reproductive process. To produce the next generation, a new chromosome called offspring is formed through a process of cross-exchange and mutation of the parent. After several generations, GA will converge on the best chromosomes which is expected to be the optimal solution. Usually initialization is randomly generated. Reproduction in particular will carry out an evaluation process with two types of operators owned by GA, namely cross-exchange and mutation so that a new chromosome called offspring will be produced. It can be stated that in GA there are only 2 (two) main operations, namely 1. Genetic operators: crossovers and mutations. 2. Evaluation operations:

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Selection. Genetic surgery mimics the process of inheriting genes in the evaluation process to produce offspring for each generation. The evaluation operation mimics the process from Darwin evolution to produce a population from one generation to the next. . If P (t) and C (t) are parents, and descendants of generation x, then the general structure of the genetic algorithm can be described as follows in figure 1. This genetic algorithm procedure is used to solve the problem of inter-city bus transportation application systems. If P (t) and C (t) are parents, and offspring at generation x, then the general structure of genetic algorithm can be described as follows figure 1 the genetic algorithm procedure is used to solve the transportation application system problem with a genetic algorithm.

```
    Procedure : Genetic Algorithm
    Begin
          t ← 0
initialize P(t);
    evaluate P(t);
          while (not termination condition) do
          recombine P(t) to yield C(t);
          evaluate C(t);
          select P(t+1) from P(t) and C(t);
          t ← t+1;
    end
end
```

Figure 1. Genetic Algorithm

10.8 Genetic Algorithms on Transportation Problems

The genetic algorithm for transportation problems is shown in Figure 2.

```
  begin
     t←0
     initialize P(t),
     evaluate P(t),
 create Pareto solution E(t),
 while (not termination condition) do
  recombine P(t)to yield C(t),
  evaluate C(t),
  select P(t+1)from P(t) and C(t),
  update Pareto solution E(t),
  t←t+1
     end
 determine the best compromise solution;
   end
```

Figure 2. Genetic algorithms to solve transportation problems

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10.9 Initialization

The procedure for initializing land transportation problems for the type of rail is described as follows:

```
Prosedure: Inisialisasi
Begin
  π ← {1,2,...,mn};
  repeat
    Pilih suatu bilangan random k dari himpunan π ;
  Tentukan baris dan kolom berdasarkan nilai k yang diperoleh;
    i ← ⌊(k − 1) / n + 1⌋;
    j ← (k − 1) mod n + 1;
Berikan nilai sejumlah units pada x_ij ;
x_ij ← min{a_i, b_j};
    update data;
    a_i ← a_i − x_ij;
    b_j ← b_j − x_ij;
    π ← π − {k};
until (π menjadi himpunan kosong)
end
```

Figure 3. Initialization of the genetic algorithm to solve transportation problems

Based on non-negative conditions and equilibrium conditions, the initialization procedure is used to produce an initial population that meets all the limitations as shown in Figure 3. The basic idea is:
(1) Selecting a random decision variable from the allocation matrix, x_{ij};
(2) Determine the number of x_{ij} units available as much as possible; and
(3) Updating supply and demand data to ensure equilibrium conditions.

10.10 Program Architecture Design

Components of the TraFAG Architecture Globally.
The TraFAG architecture is made up of 4 components:
1. The components of the initial solution.
   This component initializes the genetic population, resulting in the initial transport solution. Initialization is carried out by means of random distribution of commodities in transportation. This component receives a fuzzy transport cost file with supply and demand and generates a population of a specified number of chromosomes in the initial generation.
2. Components of the genetic operator.
   This component is used to produce new chromosomes from the latest generation chromosomes. This component has 2 subcomponents, namely cross-exchange (crossover) and mutation :
   a. Mutation component, which is a component that mutates chromosomes into new

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chromosomes. The mutation result is determined by the mutation percentage. The greater the mutation percentage, the greater the difference between the chromosomes and the original chromosomes.

b. Crossover Components. Cross-exchange 2 chromosomes from the current population that is randomly selected.

3. Evaluation and Selection.

   Components It is used to make a selection from the latest generation chromosomes and the results of crossovers and mutations to get the chromosome population in the next generation. Selection to select the chromosomes with the best fitness function.

4. The components that form the final solution.

   To select the best chromosomes across generations to get a transport solution.

   a. Inputs and Outputs of Transformer Architecture The TraFAG architecture has system inputs and outputs.
   b. System Input Inputs to the system are fuzzy transportation costs, demand and supply. The input is stored in a file.
   c. System Output The output of the system is transportation distribution and fuzzy transportation total cost.

The program design architecture overview explains the process and steps for solving railways transportation problems using genetic algorithms and fuzzy logic. Figure 4 Architecture Design is the steps or stages used to solve the problem of transportation application systems with genetic algorithms.

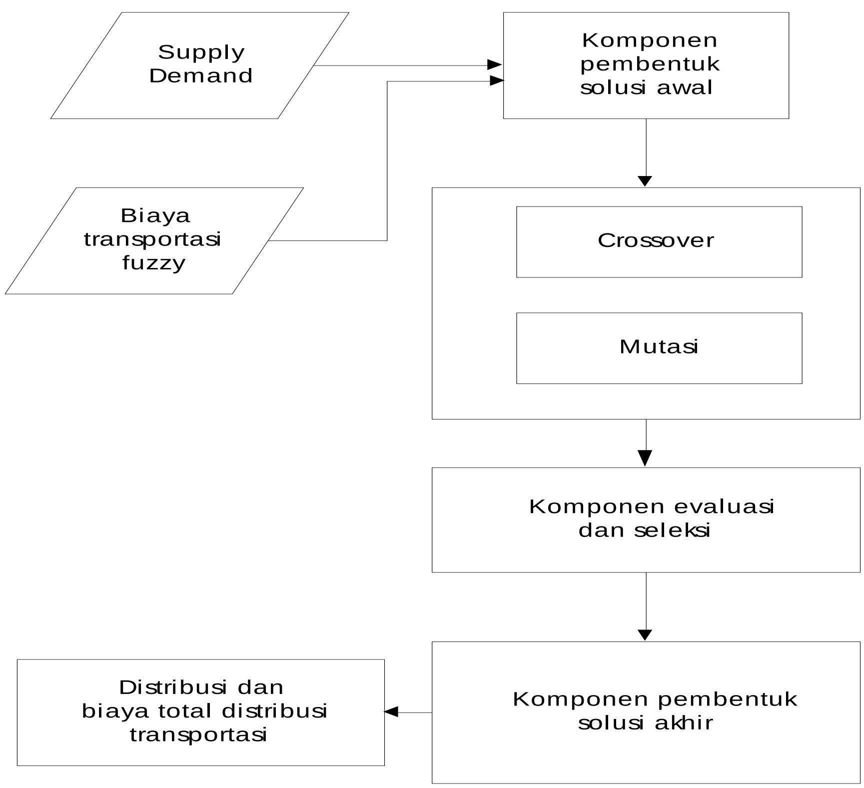

Figure 4. Architecture Design.

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10.11 Evaluation Function

Individuals are evaluated based on the fitness function. The fitness function evaluation process will continue until these criteria are met. "The fitness value of each individual (chromosome) is directly related to the objective function value.

Using a binary representation, the fitness value for individual i (fi) can be calculated using the formula:
where S_{ij} is the value of the -jth bit (column) which corresponds to the with
individual and C_j is the cost of the j-th bit (column) [4].

The selection of individuals in the reproduction process is carried out probabilistically, where one individual in the population can be selected more than once to produce the next generation. There are several selection methods, including proposition selection, roulete wheel selection, fitness scaling techniques, tournament elitist models and ranking methods [4].

The proportional selection method (proposition selection) calculates the individual probability (Pj) to be selected by the formula:
Pi = Where P_i is the fitness value of the i^{th} individual and is the chromosome evaluation function.

10.12 Reproduction

Reproduction is the process of copying individual strings based on their destination function values. In genetics the objective function is called fitness [16]. This function can be used as a measure of profit or utility that will be maximized. Copying the string means that the string which has a higher value, is less likely to participate in the formation of the offspring.

New individuals who are reproduced, usually individuals with fitness values above average, will randomly replace old individuals in the population. This replacement method is called incremental replacement or steady state replacement [4].

Besides that, there is a generation or replacement method, where a new generation population is produced as a whole and then it will replace all parent populations. The results of this study [4] show that the use of the steady state replacement method in individual replacement gives better results when compared to the generational replacement method.
The advantage of using the steady state replacement method is that individuals with good fitness values will almost always produce the newest generation.

The process of replacement individuals (parents) in the new population (child) will continue until the termination conditions are found. Generally, this termination condition uses the maximum number of generations.

10.13 Initial Value Search Process Conventional Approach GA Approach

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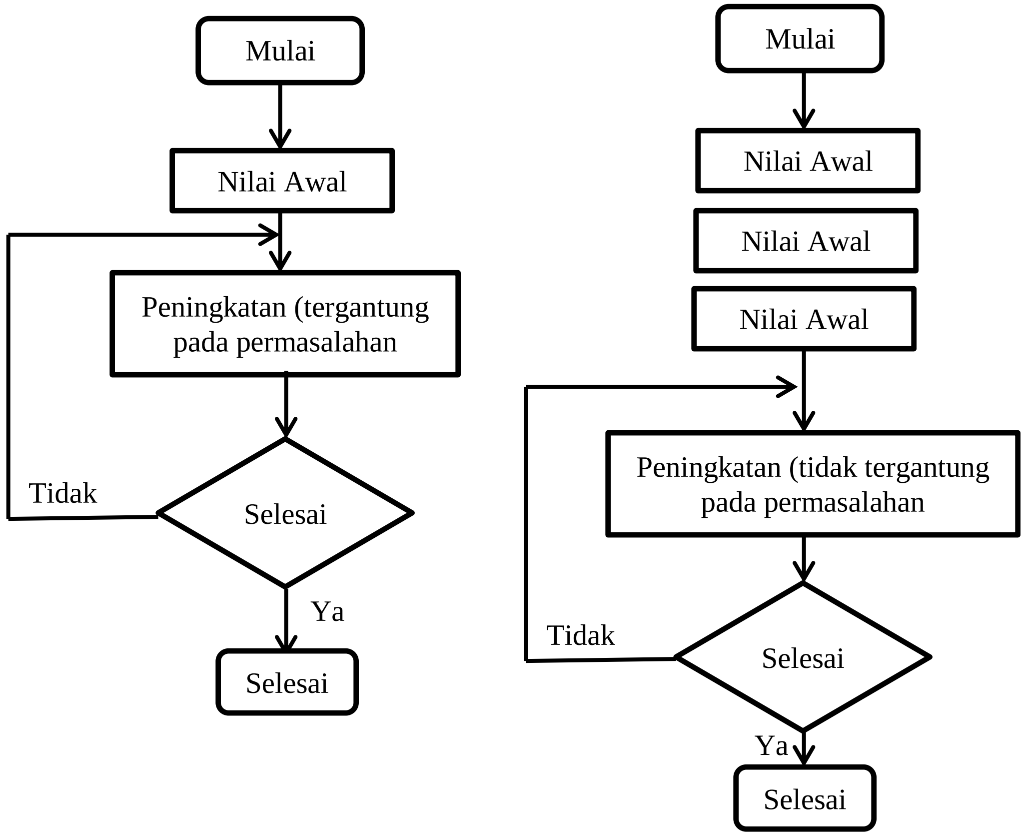

Figure 5. Comparison of conventional approaches with GA

10.14 Differences Between Conventional and GA Approaches

"Most classical optimization methods include a deterministic sequence of computations based on a gradient or higher order derivative of the objective function [15]". This method is used in the search for space. "This point to point approach can spread to optimal locales. GA performs multiple directional searches by keeping a population of potential solutions [11] ". In the conventional algorithm approach, the search for a solution starts from one initial value, then the algorithm exploits that initial value through a series of iterations [3]. The difference between conventional and GA approaches can be seen in Figure 5.

10.15 Transportation Problems

The problem of transportation addresses the shipping of the same commodity from several sources to a number of destinations. Each source and destination has a supply and demand for certain quantities of commodities. The purpose of solving this problem is to allocate the inventory of each source to meet the needs of each objective in such a way as to optimize the specified criteria. Usually used to minimize overall costs.

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10.16 Problem formulation

By using the terms **m** sources and **n** destinations, the transportation problem can be formulated as follows:

Minimization $$z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \quad (1)$$

Constraint function:

$$\sum_{j=1}^{n} x_{ij} = a_i \quad , \quad i = 1, 2, \ldots, \mathrm{m} \quad (2)$$

$$\sum_{i=1}^{m} x_{ij} = b_j \quad , \quad j = 1, 2, \ldots, \mathrm{n} \quad (3)$$

$$x_{ij} \geq 0 \quad , \quad \forall\ i,j \quad (4)$$

with:

x_{ij} = number of units of goods sent from source i to destination j
c_{ij} = the cost of sending one unit of goods from source i to destination j
a_i = the amount of supply at source i
b_j = number of requests on destination j

10.17 Representation of transportation problems

The transportation problem can be described in graph form as shown in Figure 6. Graph consists of source vertices O_i , i = 1, 2, …, m. Destination vertices D_j , j = 1, 2, …, n, as well as set of arcs connecting the source and destination vertices. The graph depicted is in the form of a bipartite graph complex.

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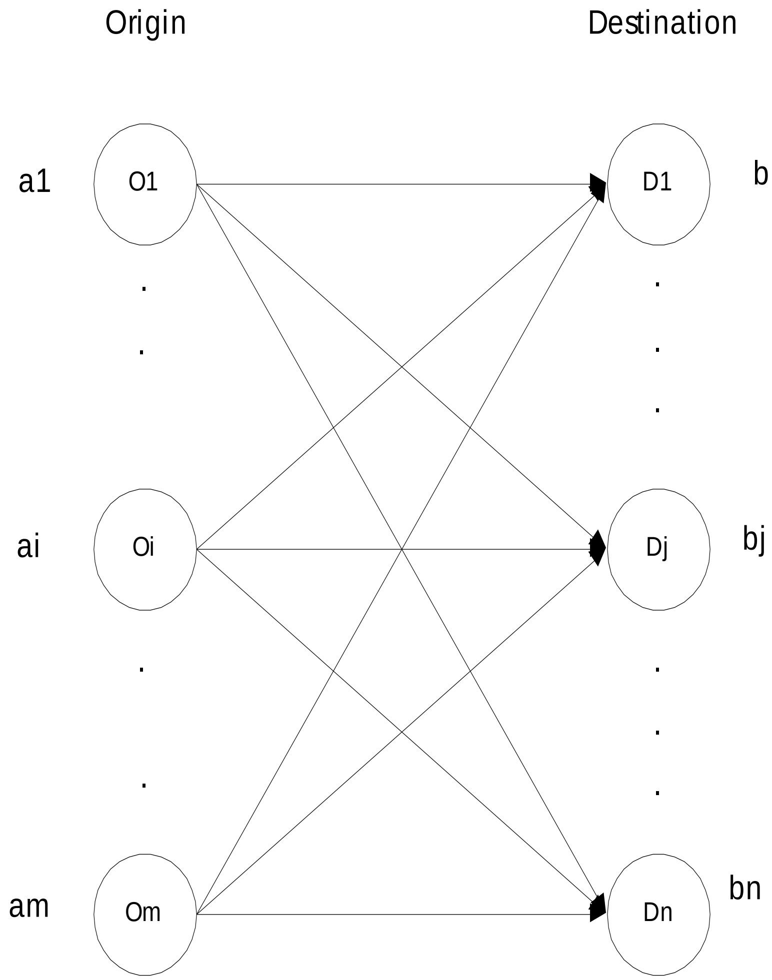

Figure 6. Graph consists of source vertices

10.18 Classification of Transportation Problems

Transportation problems can be divided according to the function of the destination and its limitations. According to its objective function, transportation problems can be separated between linear and nonlinear, as well as between single criteria and multiple criteria.
According to its limits, transportation problems can be separated between solid and planar, and between equilibrium and unbalanced. By using transportation problem the total transport cost and commodity allocation can be predicated [1].

10.19 Linear and Nonlinear Transportation

The transportation problem is called linear if the cost of sending goods from source to destination has a straight ratio with the number of units of goods shipped. If not, the transportation problem is said to be non-linear.

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10.20 Single Criteria and Multiple Criteria Transportation

Transportation problems with a single criterion, such as cost minimization, have been widely resolved and written in various literatures. But in reality, other fields require criteria other than cost, such as time criteria and transport eligibility criteria. This multiple criteria transportation problem has more than one objective function. The resulting types of transportation problems are multi-objective. A special case of multi-objective transportation problems that can be described in two-dimensional criteria space is a double-criteria transportation problem, namely a transportation problem that has two objective functions.

There are 3 main methods of multi-objective case resolution as follows:

a. Weighting method, which is an approach by expressing all objective functions into one objective function. From a computational point of view, this method is interesting by varying the weights. The downside is that it determines the weights that actually correspond to reality.

b. The ranking or priority method, namely determining the ranking / priority of each objective function, according to importance.

c. Non-domination method, by looking for all non-dominating solutions. A solution is called non-dominating if, and only if, each solution of the current objective function is less than the result of the solution of the objective function.

This method also called the efficient solution, the Pareto optimal solution or the non inferior solution.

10.21 Planar and Solid Transportation

Transportation problems are called planar if the transport vehicles are the same, and do not have a limit on the number of units to be transported. If there are different transport vehicles this is called a solid transportation problem. This problem is commonly found in general distribution systems and is usually applied to transportation problems that have more than one criterion.

10.22 Balanced and Unbalanced Transportation

The transportation problem is called equilibrium if the quantity of goods supplied is equal to the quantity of goods needed. If not, then the transportation problem is unbalanced.

The balanced transportation problem uses the equation below.

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j \qquad (5)$$

Assuming equilibrium conditions, transportation problems always have a solution.
For example, one solution is:

$$x_{ij} = \frac{a_i b_j}{\sum_i a_i} \quad , \quad i = 1,2,\ldots,m, \quad j = 1,2,\ldots,n \qquad (6)$$

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Every solution, every xij value always satisfies
$0 \leq x_{ij} \leq \min \{a_i, b_j\}$

10.23 Multiple Criteria Transportation Problem with Fuzzy Cost Parameters

In the transportation system, the effect of congestion on transportation means results in uncertainty in part or all of the coefficients on objective functions, such as transportation costs or delivery times which become uncertain [5]. Mathematically transportation problems can use the formula below:

Minimization $$z_q = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}^{q} x_{ij} \quad , \qquad q = 1,2 \qquad (7)$$

Obstacles:

$$\sum_{j=1}^{n} x_{ij} = a_{i,} \quad , \qquad i = 1, 2, \ldots, m \qquad (8)$$

$$\sum_{i=1}^{m} x_{ij} = b_{j,} \quad , \qquad j = 1, 2, \ldots, n \qquad (9)$$

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j \qquad (10)$$

$$x_{ij} \geq 0 \quad , \qquad \forall\, i,j \qquad (11)$$
$$a_i > 0 \quad , \qquad \forall\, i \qquad (12)$$
$$b_j > 0 \quad , \qquad \forall\, j \qquad (13)$$
$$c_{ij}^{q} \geq 0 \quad , \qquad \forall\, i,j,q \qquad (14)$$
$$q = 1,2 \qquad (15)$$

With:

x_{ij} = number of units sent from source i to destination j
c_{ij}^{q} = the cost of sending one unit of goods from source i to destination j
a_i = the amount of supply at source i
b_j = number of requests on destination j

10.24 System Development Methodology

Can use object-oriented programming, Rational Rose, Waterfall and others. The system engineering work cycle uses the waterfall model [21]. In simple terms the system engineering work cycle can be described as follows:

1. System Engineering.
   Making a software is the biggest part of a project. For work begins with determining all the things that are necessary in the implementation of the project.

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2. System requirements analysis
   Analysis is the stage where system engineering analyzes the things that are needed in the implementation of a software development or development project.
3. Design.
   This stage is the translation of the analyzed needs or data into a form that is easy for the user to understand.
4. Coding.
   The next stage is translating data or problem solving that has been designed into a predetermined computer programming language.
4. Testing.
   After the program is finished, the next step is testing.

10.25 Implementation Program

In this section, we will describe the implementation of the program that has been carried out in accordance with the factoring results that have been produced at the design stage. Program structure is a form of functional decomposition. The program structure is in the form of a tree diagram that defines the overall program architecture by showing the program modules and the relationships between them. The program structure is formed by factoring. The results of factoring and their association with the process in the data flow diagram are presented in the table 1.

The implementation of the design results is built using the Delphi programming language [6]. Program implementation based on the results of factoring. This section describes the implementation of the program that has been carried out in accordance with the factoring results that have been produced at the design stage. The implementation table of factoring results can be seen in table 1.

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Table 1. Implementation of the factoring results

FACTORING	MODULE	PROCEDURE
1. Read	UTraFAG	Take1Click
1.1 Edit	UKriteria1&2	Edit l Click
1.2 Setting	UTraFAG	Parameter of the GA1Click, Parameter*Fuzzy*1Click, ParameterTransportationClick
1.3. Check The Balance Condition	UGenetics	Test Supply Demand
2. Initialization	UGenetics	Initialization Population
3. Recombination	UGenetics	Recombination
3.1Selection chromosome crossover	UGenetics	Select the crossover chromosome
3.2Selection chromosome mutated	UGenetics	Select the mutated chromosome
3.3 Crossover	UGenetics	Crossover
3.4 Mutations	UGenetics	Mutation
3.4.1 Create Sub Matrix	UGenetics	Create Sub Matrix
3.4.2 Reallocation	UGenetics	Reallocation
3.4.3 Replace	UGenetics	Replace
4. Evaluation	UGenetics	Evaluate
4.1 Evaluation criteria 1	UGenetics	Evaluate1
4.2 Evaluation criteria 2	UGenetics	Evaluate2
5. Selection	UGenetics	Selection
5.1 Calculate The Fitness Function	UGenetics	Calculate fitness
5.2 Sorting fitness	USorting	Sorting fitness
5.3 Merging of chromosome	USorting	Merging
6 Solution Pareto	UGenetics	Solution Pareto
7. Topsis	UGenetics	Topsis

10.26 Implementation of Procedures

The kinds of factorization result procedures used in this program can be seen in the figure 7 below. Figure 7 below is the main procedure for the genetic algorithm. Various kinds of factorization result procedures used in this program can be seen in the figure 7 below.

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```
procedure TFTraFAG Genetic Algorithm;
begin
 x: =0;
  InitializePopulation(A);
  Evaluate(A,PopSize);
  SolusiPareto(A,PopSize);
  while x<maxgen do
  begin
    ProgressBar1.Position:=round(x/MaxGen*100);
    Rekombinasi(A,Q,R,round(PCross*PopSize),round(PMutation*PopSize));
    Evaluate(A,PopSize);
    Select(A,Q,R,round(ACross*PopSize),round(AMutation*PopSize));
    SolusiPareto(A,PopSize);
    Inc(x);
  end;
  Topsis(A,BestPop);
end;
```

Figure 7. Main procedure for the genetic algorithm

10.27 Procedures reading data

Figure 8 below is a procedure for reading transportation data in program implementation TRAFAG transportation problems, along with testing the equilibrium conditions on the data.

```
procedure TFTraFAG.Take1Click (Sender: TObject);
begin
  if OpenDialog1.Execute then
    if FileExists(OpenDialog1.FileName) then
    begin
      LoadDataFromFile (OpenDialog1.FileName);
      FormCreate (Sender);
    end;
end;
```

Figure 8. Procedure for reading transportation data

10.28 Algorithm for Parameter Setting

Algorithm for Parameter Settings can be seen in Figure 9 below. The algorithm in Figure 9 below has the following functions and is used:

a. To display the form for filling in the genetic algorithm parameters.
b. To display an alpha value filling form.
c. To display the Transportation parameter filling form.

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```
procedure TFTraFAG.ParameterGA1Click (Sender: TObject);
begin
   FParamGA.ShowModal;
end;
procedure TFTraFAG.ParameterFuzzy1Click (Sender: TObject);
begin
  FParamFuzzy.ShowModal;
end;
procedure TFTraFAG.ParameterTransportasi1Click (Sender: TObject);
begin
   FParamTrans.ShowModal;
end;
```

Figure 9. Algorithm for Parameter Settings

10.29 Examples of Research Results and Discussion of Genetic Algorithm

The amount of memory needed to implement the program and the results of the analysis from the tests that have been carried out on the genetic algorithm application program for transportation problems. Testing 15 test cases, namely test cases 2 to 15 test cases. Each case states the number of source depots and destination depots. The test results that have been done are the effect of the number of depots. Effect of population size. Effect of the number of generations on processing time. Effect of alpha parameters on the integral value. The effect of the number of generations. Effect of population size. Effect alpha parameter, the crossover probability, the probability of mutation on the fitness function.

10.30 Memory Requirements

Memory requirements the memory needed to create an application program can be summarized as follows:

1. Source Compiled: 2587 lines.
2. Code Size: 439355 bytes.
3. Data Size: 2289116 bytes.

10.31 The Effect of the Number of Transportation Source Depots on Processing Time

Figure 10. shows that the larger the test case, the longer the processing time will be used to complete. In each test case reflects the matrix order, the processing time in the test case will be directly proportional to the product of the number of source and destination depots with a correlation coefficient of 0.87.

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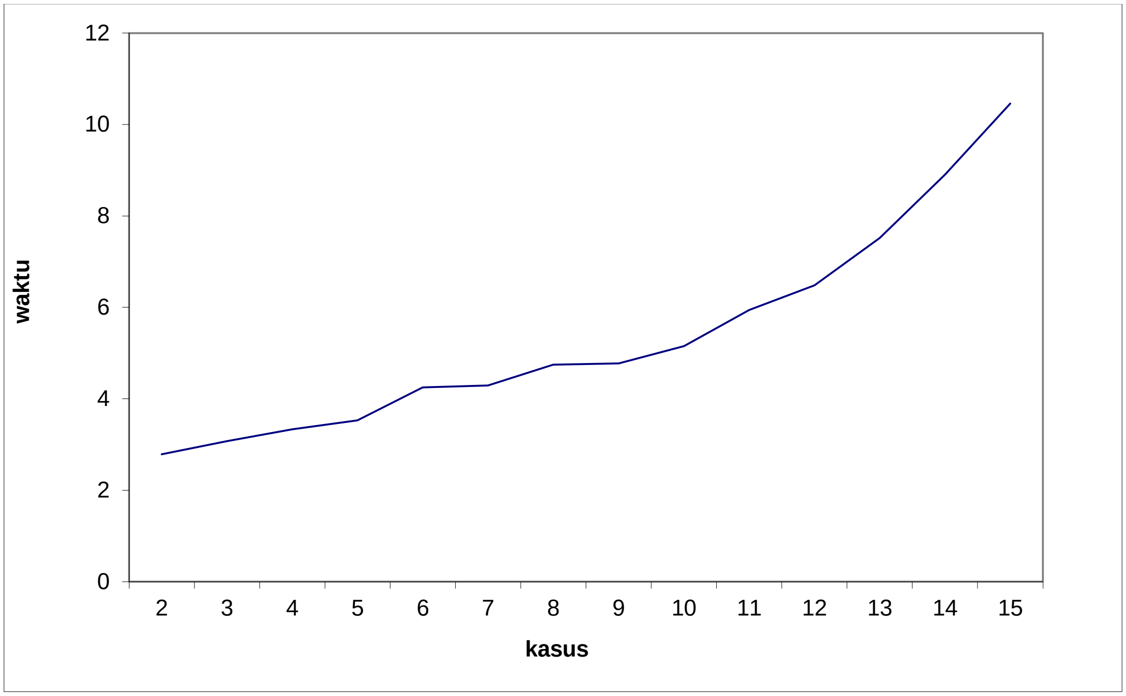

Figure 10. Graph of the effect of the number of depots on processing time

10.32 Effect of Population on Processing Time

Figure 10. Shows that the number of populations has an effect on the greater processing time. The effect of population size on processing time is linearly proportional to each test case with a correlation coefficient of 0.97. Figure 11. is shown for test cases 5, 10 and case 15.

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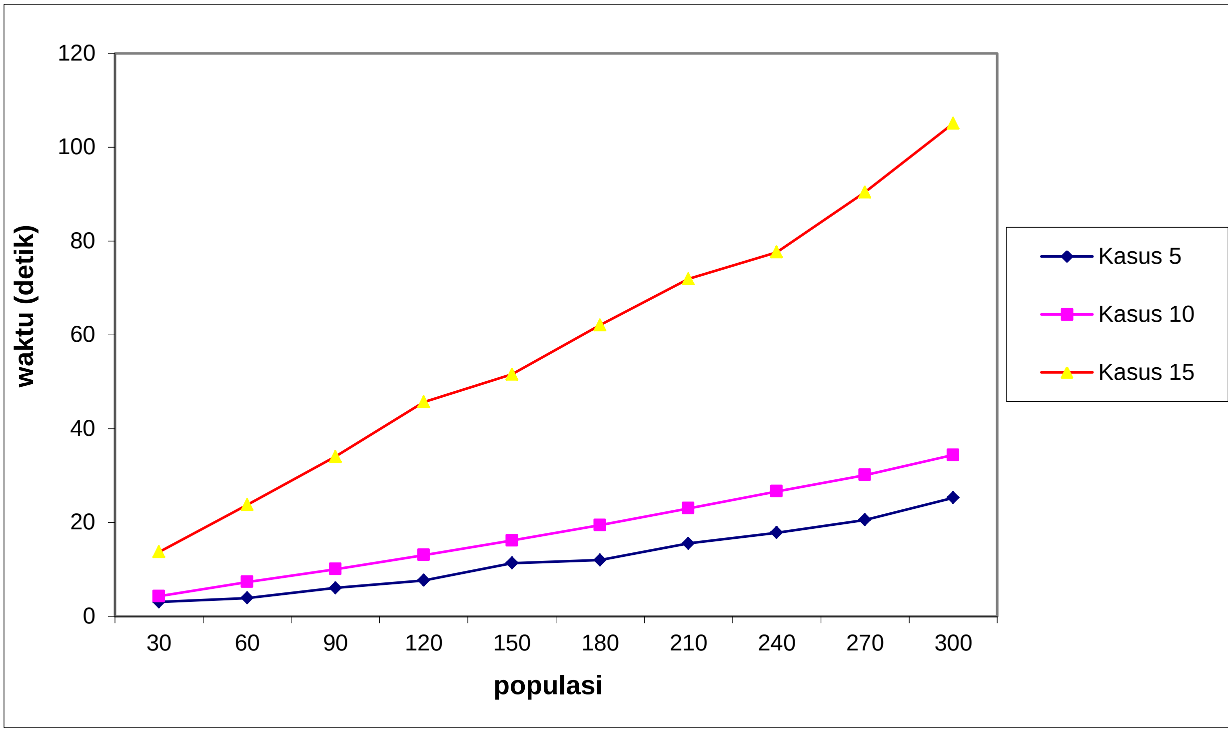

Figure 11. Graph of population against processing time

Based on the results that have been carried out at the analysis, design and implementation and testing stages, conclusions can be drawn as follows:

1. The solution to transportation problems, for certain criteria can be solved using genetic algorithms. Because genetic algorithm works with coding solutions. Genetic algorithm searches from population solutions. Genetic algorithm uses the results of the fitness function and uses probability transition rules. In calculating the fitness function, the two criteria use the optimal pareto value. The optimal Pareto solution in a fuzzy environment is determined by fuzzy ranking, and all objective functions must be considered.
2. Analysis of program results shows that the processing time in the test case will be directly proportional to the product of the number of source depots and destination depots with a correlation coefficient of 0.87. The results of the analysis show the population size, is directly proportional to the test cases to processing time with a correlation coefficient of 0.97.

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10.33 Exercises

1. How do you calculate the fitness value in the genetic algorithms?
2. How do you calculate the population for each individual in genetic algorithms?
3. Describe the terms in genetic algorithms?
4. Please give examples of implementing problem solving using that term?
5. To solve the optimization problem, genetic algorithms are more suitable for solving the problems you mentioned?
6. How do you calculate the fitness value for each individual (chromosome)?
7. How is the reproduction process in genetic algorithms?
8. Make an example of the application of problem cases solved by genetic algorithms?
9. Make a simple application to solve optimization problems using genetic algorithms?
10. Describe and give examples of applying the problem using the steady state replacement method in individual replacements to give better results?
11. Explain and prove the generational replacement method with the steady state replacement method. Which of the two methods is better to use? in individual replacement to give better results?
12. What are the various terms contained in genetic algorithms?
13. How do you calculate the fuzzy cost parameter for bus transportation between cities uses the triangular fuzzy number?
14. How do you calculate the optimal value uses the pareto solution?
15. Describe the genetic algorithms process?
16. Explain the principle of the fuzzy number?
17. Explain the transportation problem discussed is planar?
18. How can the type of transportation be said to be balanced?
19. Explain how transportation can be said to be linear and give examples of these problems?

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20. Explain the advantages of genetic algorithms and give examples of problems about the genetic algorithm?

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Fuzzy
Fitness Function
G : Genetic algorithm
Generations
H : Heuristic
I : Implementation
Inter-city bus
Integral
Indicates
M : Methodology
Mutation
O : Optimization
Objective functions
P : Pareto solution
Population
Parameter
Probability
S : Selection
Source
Sorting
T : Transportation
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Triangular fuzzy number
Transportation Fuzzy Algorithm Genetic
V : Value
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