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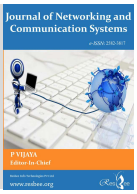

Fuzzy Logic Project Scheduling Application with Limited Resources on Development Irrigation Project on Java Island

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Abstract: On the island of Java, there are many very large areas for agriculture and the development of food cropcultivation such as rice plants, secondary crops, vegetable plants, fruit plants, organic plants, and so on.This area needs an irrigation project from the government to irrigate the crops planted byfarmers on the island of Java. This area often experiences floods, landslides, and droughts due to a lack ofwater. So that agricultural products and food crop cultivation, farmers and the community get optimalresults and can be used as a good livelihood for farmers.It is necessary to develop this irrigationproject to knowthe conditions that are very worrying for farmers. So this softwarewas built to solve the problem of allocating renewable resourcesbetween activities that have a logical implementation sequence and do not hinder each other whichcannot be determined to minimize the function of the makepan project completion time criteria withintime parameters, including ready time, duration, timeout time, start time and end time are uncertain.The uncertainty of the time parameters is modeled as fuzzy numbers of type I-Left, I-Right, α, ß, LR,with three α-cuts {E = 0.5, L=0.8, and I=1.0}. This fuzzy model is transformed into a deterministic model based on three pairs of inferiorand superiorα-cutvalues. Activity scheduling priority rules are based on the smallest initial start time value. Resource usage conflicts are resolved in two ways, namelyserial and parallel models. The best solution is determined based on the smallest makespan value.Solving this problem involves operations on fuzzy values, including arithmetic operations and relationaloperations that have certain rules. This software provides two types of schedules, namely optimistic and pessimistic schedules.The resultof creating this system is that it can solve the problem of allocation of renewable irrigation resourcesand renewable resources between activities, which have a logical implementation sequence and do nothinder each other. So, the results can minimize the makespan project completion time in terms of timeparameters, including ready time, duration, deadline time,uncertainstart time, and endtime.

Keywords: Project Scheduling; Fuzzy Logic Time Parameters; Makespan Criteria; Optimistic and Pessimistic Schedules.

Table1.Nomenclature

Abbreviation	Expansion
RCPS	Resource Constraints Project Scheduling
PERT	Project Evaluation and Review Technique
CPM	Critical Path Method
OPT	Oriented Process Technical
AI	Artificial Intelligence
OR	Oriented Real
DSS	Decision Support System
AON	Activity On Nodes
RPWM	Ranked Positional Weight Method
OOA	Object-Directed Analysis
OOD	Object-Directed Design
OOP	Object-Directed Programming
VCL	Visual Component Library
JPF	Fuzzy Project Schedule
CRC	Class Responsibility Collaboration
AON	Activity-On- Node
OOT	Object-Oriented Software Testing
CDS	Campbell Dudek Smith
NEH	Nawaz Enscore Ham
FCFS	First Come First Served
MPS	Master Production Schedule

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1. Introduction

Project scheduling is a very important and urgent matter in carrying out every project activity for scheduling irrigation development projects on the island of Java by optimizing the efficiency and effectiveness of the use of existing time and resources. But still, we have to maintain and prioritize appropriate priorities between ongoing project activities. To overcome this, it is necessary to model project scheduling with resource supply constraints and to implement it closer to the real world. This RCPS model is very suitable to be implemented. The models have been developed in multi-category resources, multi-mode activity formation, multi-criteria functions, and the combination of the three modes. One aspect that has so far received little attention in modeling RCPS problems is the uncertainty characteristic of time parameters and the implementation of each activity in a project. This can be handled using the PERT method with a probabilistic approach. The probabilistic approach can only be used if historical data is available regarding the experience of implementing similar projects. If the project is new both the techniques and methodology used to carry out the project are completely new. For example, several new techniques and methodologies in software engineering including Object-oriented design and programming, Assisted software design computers, User interface management Systems, and fourth-generation languages. It is no longer possible to use a probabilistic approach. In a situation like this, a decision-maker must be able to estimate the duration of each activity in a project based on the experience methodologies the level of available expertise, and human resources.

Looking at the problems mentioned above, this make span minimization estimation method is more suitable to be represented in the form of fuzzy numbers, namely fuzzy sets in the universe of real numbers whose intervals are normal, convex, and closed. Able to solve scheduling problems with good and optimal results. The main contribution of the project is

- To address the problem of allocating resources between the project and the project completion time.
- To propose a deterministic model based on the inferior and superior values and to resolve the conflicts based on the smallest Make span.
- To provide a software solution that can effectively allocate irrigation resources and minimize project completion time in terms of various time parameters.

The paper's result is the development of a software system that effectively allocates irrigation resources and minimizes project completion time in terms of various time parameters.

The paper is organized as follows: Section 2 covers the Literature review. Section 3 details the Software Architecture of JPF. Section 4 explains the Project Scheduling. Section 5 mentions the Project Scheduling Methods. Section 6 represents the programming. Section 7 mentions implementation. Section 8 explains the testing of results. Section 9 details the discussion. Section 10 points to the Advantages and Disadvantages of the proposed method. The conclusion is recapitulated in Section 11.

2. Literature Review

In 2020, Annisya, S.D, *et al.,* [2] discussed the scheduling of production in a manufacturing company to reduce the Make span, which is the total time required to complete all jobs. The company was involved in the production of refractory stones. The study compared three scheduling methods: CDS, NEH, and Palmer. The results showed that the CDS method has a smaller Make span compared to the company's current method, resulting in a cost-saving of 140,290 seconds (8.82%).

In 2022, Baharuddin, *et al.,*[3] measured the working time in a small-scale donut production industry to determine the standard time required by employees to complete a job. The study aimed to determine cycle time, normal time, and time standard for each work element, as well as the standard output produced by each worker. The time measurement resulted in a standard total of 204.5 minutes and a standard output of 3 seeds/minute or 2700 seeds/day to determine the standard time and workload in the production process of a specific skincare product.

In 2020, Sari, E. M., [12] focused on the design of production scheduling in a manufacturing company and the use of MPS and CDS methods to improve the effectiveness of production scheduling. The study aimed to reduce the Make span value, which is currently high, causing disruptions in the production schedule. The analysis showed that the implementation of the CDS method results in a significant decrease in the Make span value leading to time savings in production.

In 2020, Sidabutar, SN *et al.,* [19] focused on the scheduling of production machines using the CDS method at PT Tjokro Bersaudara Balik papanindo. The goal was to optimize the scheduling process and minimize the Make span, which was the total processing time. Currently, the company uses the FCFS scheduling method, which leads to delays. The study compares the results of scheduling using the CDS

method and the FCFS method. It is found that the CDS method produces a smaller Makespan indicating better scheduling efficiency.

In 2020, Sari, E. M., & Darmawan, M. M [11] determined the standard time and workload in the production process of a specific skincare product. The research involved analysis of tasks performed by operators in the filling and packing stations, calculating their work time, estimating the demand, determining the workload for each station, and identifying the appropriate number of workers. The results showed that certain tasks have a workload below 100%, leading to a reduction in the number of operators, while one task has an excessive workload of 114% and requires overtime.

2.1 Review

Table 1 portrays the methodology, advantages, and disadvantages of the existing method. We considered five papers that used a different methodology for project scheduling. Each method has certain benefits and shortcomings that were explained in detail.

Table 1. *Review Based on Existing Methods*

Author	Methodology	Advantage	Disadvantage	Broadcast Address
Annisya S.D *et al.*[2]	CDS, NEH, And Palmer	• More effective for refractory stones, reducing the total processing time and meeting consumer demand on time. • Used systematic approach. • Better coordination and allocation of resources. • Improved productivity.	• Involves a lot of labour. • The applicability and effectiveness of these methods may vary depending on the specific context and characteristics of the manufacturing company. • Further research was required to implement scheduling methods in different production environments.	192.168.1.31
Baharuddin A. *et al.* [3]	Time study method	• Accurate measurement of the working time required by employees to complete specific tasks. • Have a fair and objective assessment. • Effective optimization of work productivity.	• Time-consuming and labor-intensive. • Required dedicated resources to conduct the observations and measurements accurately.	192.168.1.63
Sari E.M [12]	MPS and CDS	• Used systematic approach. • Accurate and reliable data collection. • Precise assessment of workload and identification of areas with excess or shortage of workers. • Improved productivity and cost-effectiveness.	• Involves a lot of labour. • The specific applicability and effectiveness of the method may vary depending on the unique characteristics and requirements of different skincare product manufacturing processes.	192.168.1.95
Sidabutar, SN *et al.* [19]	CDS	• It is efficient in scheduling production operations. • Reduces the total processing time, improves productivity, and timely completion of the job.	• The implementation of this method is costly.	192.168.1.127
SariE.M and Darmawan M [11]	Westinghouse method	• It provides reliable data for analysis and decision-making regarding workload and staffing requirements. • The method provides a systematic approach to analyzing the work performed by operators, estimating demand, and determining the appropriate number of workers, contributing to effective workforce planning and management.	• It is not a systematic approach. • It is costly.	192.168.1.159

2.2 Research Gap

Based on the analysis of the papers above, the problems faced in project scheduling were minimizing project work time, minimum costs, and labor. We can overcome this using the make span minimization method. The main benefit is that the project can be completed quickly with minimal cost. Performance about Time influences, cost performance, and overall project performance variables are monitored and the results are evaluated such as quality, work safety, availability of equipment and materials, the original plan, evaluation, and corrective actions. The project should be successful and safe in controlled conditions with optimal project targets at minimal costs in terms of costs, time, and labor. So that the project objectives can be met and the results will be optimal.

3. Software Architecture JPF

The JPF software architecture consists of a project scheduling component and a user interface component. The project scheduling component provides two scheduling methods, namely the serial method and the parallel method. The user interface component regulates the reception of input data and the presentation of output results in graphical form.

Input Data:

- Resource table consisting of resource number, name, type, and quality.
- Activity table consisting of number, name, precursor, resource allocation, ready time (Optional), duration, and deadline time (Optional).

Output Results:

- Activity Table consists of a number, name, precursor, resource allocation, ready time (Optional), duration, deadline time (Optional), start time, and end time.
- The graph represents the allocation of resource requirements for an activity (Resource requirements).
- Graphs that represent the profile of the use of certain resources within the time span of carrying out activities (Resource profile).
- Graph that represents a network of activities (precedence constraints) with an AON representation model.
- Graph that represents the fuzzy makes pan of a project (Project makes pan).
- Graph that represents the activity implementation schedule in the form of a fuzzy Gantt chart.

Fig. 1 represents the architecture of JPF.

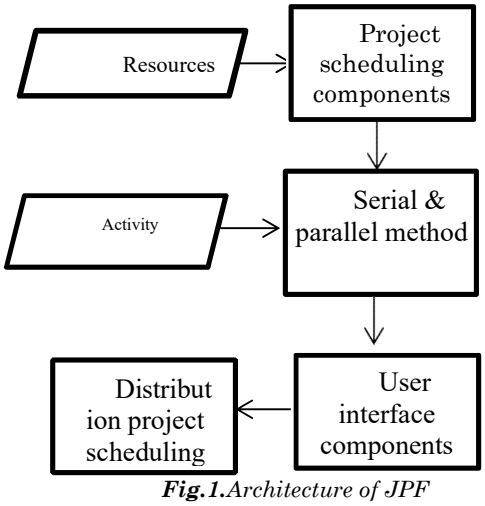

Fig.1.*Architecture of JPF*

4. Project Scheduling

Project scheduling management has experienced rapid development along with the determination of two analytical methods for planning, scheduling, and controlling a project [13]. These two methods were developed during the same period (1956-1958) by two different groups. PERT was developed by a consulting company used for scheduling research and development projects for the Polaris missile program within the United States Navy (US-Navy) [14], while CPM was first developed by E.I. duPont

de Nemours & Company and further developed by Mauchly Associates [15] for construction projects. Indonesia is an agricultural country that has very extensive agricultural land in areas including the island of Java [16]. Many residents choose to become farmers as a livelihood. They grow various plants such as rice, secondary crops, fruit, vegetables, organic plants, and many other types of plants. However, these farmers experience difficulties regarding irrigation water to irrigate their fields and crops [17]. Especially during the dry season and El Nino season. Many farmers complain about the lack ofair to irrigate the crops in their fields. The water availability is very difficult. So the irrigation project is essential for farmers to get optimal results in every harvest. So if the agricultural results are good and optimal for many farmers. Then the price so fall good sand food stuffs become cheap and affordable. If agricultural output decreases, the price of basic food commodities will become expensive. So that the entire community will feel the negative impact of agricultural products. PERT and CPM are project scheduling methods that are solely time-oriented because they ignore resource supply constraints [18]. The difference between these two methods is that they are probabilistic, while the CPM method uses deterministic time estimation. Subsequently, these two methods were combined into one known as the PERT-CPM method. The planning phase begins by dividing (breaking down) the project into several activities, determining resource requirements and the duration of each activity, followed by creating an activity network that presents the preferences between activities in graphical form. The scheduling phase aims to determine the start and end time of each activity by the existing preferences between these activities and can show which activities are on the critical path in the network of activities that require special attention so that the project can be completed on time. The control phase aims to periodically evaluate the progress of project implementation, and if the implementation is too fast or too slow, then the schedule for subsequent activities must be reviewed. The project scheduling problem is characterized by four components they are a set of resources, a set of activities, a set of preferences between activities, and a set of function criteria, a same a sure of project implementation performance.

$$S = \{R, Z, P, C\} \tag{1}$$

Where R is the set of resources, Z is a set of activities, P is a set of preferences between activities, and C is a set of function criteria.

4.1 Resources

R resources are divided into three categories, as follows:

a. Renewable resources consist of P types, namely $R_{1r} \ldots R_{pr}$, where R_{pr} with respective supply limits of $N_{1r} \ldots N_{pr}$, N_{1r} is the units for each time period.

b. Non-renewable resources, consisting of types, namely $R_{1n} \ldots R_{vn}$, R_{in} with respective supply limits of $B_{1n} \ldots B_{vn}$, B_{vn} units decrease in proportion to the amount of use.

c. Doubly-constrained resources consist of u types, namely $R_{1d} \ldots R_{ud}$, R_{ud} with are new able supply limit each of $N_{1d} \ldots N_{pd}$, N_{pd} non-renewable initial stock limit units each of $B_{1d} \ldots B_{vd}$, B_{vd} units [2].

4.2 Fuzzy Data Representation

Aspects of uncertainty are currently studied in efforts to develop system models that are closer to the real world [3]. In the traditional view, science is synonymous with certainty in all its manifestations (precision, specificity, sharpness, consistency, and so on) and all forms of uncertainty are considered unscientific in the modern view. Uncertainty is considered essential and does not need to be avoided because of is representative of the real world. Each model must pay attention to three basic characteristics as a benchmark for approaching the real world namely the level of complexity, level of reliability, and uncertainty [19]. Uncertainty has an important role in maximizing the usefulness of a system model. In general, the system becomes more tolerant of uncertainty and more system reliability.

4.3 Fuzzy Sets

In 1965, Lotfi A. Zadeh offered a fuzzy set theory to represent a vague uncertainty for the object that has membership with imprecision boundaries [20]. Membership in a fuzzy set is not based on the crisp Aristotelian dual-valued logic theory (affirmation = full member and denial = not a member) but on acertain degree of membership or membership function [21].The membership function begins with a number value that lies in the interval [0.1] with extreme values of 0 and 1 indicating denial and affiliation to their membership respectively.

4.4 Heuristic Functions for Minimizing Make span

Scheduling is an NP-complete problem, where the number of possible solutions is combinatoric, making it impossible to find every solution in the solution space [3]. The heuristic function plays a role in reducing the solution space to obtain the solutions quickly. Although it does not necessarily provide the absolute optimum solution. There are 12 heuristic functions that heuristic function can be applied to fuzzy project scheduling to capture solutions that provide the smallest make span value, namely: MINEST, MINEFT, MINLFT, MINLST, MINSLAK, SPT, LPT, LRPW, GRPW, LIS, MIS, GRD.

5. Project Scheduling Methods

Many studies have been conducted related to scheduling problems [25].In general, scheduling problem-solving methods include project scheduling. It can be categorized as follows:

a. **Manual Scheduling**
   This method requires a high effort that incorporates unstructured human expertise in to the process.
b. **Computer Simulation Scheduling**
   This method uses statistical functions to simulate scheduling behavior in the real world using a computer a sanauxiliary tool.
c. **Mathematical Approach**
   This method uses operational research such as Integer programming, Dynamic Programming, and heuristic methods (E.g. Neighborhood search).
d. **Dynamic Bottlenecks**
   This method includes estimated costs that must be incurred if there is a delay in the implementation of one or several activities during the trip.
e. **New Method**
   This category of methods includes met a heuristics based on intensification or diversification to achieve problem- solving results (e.g., Taboo search, Simulated annealing, and Genetic algorithm), Partial Enumeration, using Beam Bottleneck, Explanation of the OPT principle, Implementation of expert systems, neural networks, and combinations of AI, OR, DSS.

5.1 Linear Scheduling Method

This method is very effective for projects with a large number of activities relatively few and widely used for scheduling activities recurring such as on highway construction projects, airport runways, tunnels, or industrial manufacturing projects. It is satisfactory to apply to such projects because it uses relatively smaller human resources and variations in skills at a time not as much work as on other projects. This method is only for projects with a large number of activities relatively few [4].

5.2 Network Scheduling Method

This method is suitable for developing control systems management and controlling large of numbers activities that have complex dependencies. The disadvantages of this method are relatively more difficult. There elation ship between activities is clear and can show critical activities. It needs to be combined with other methods to make it more informative. The advantage of network planning information and corrective actions can be done later by updating the schedule.

5.3 Method PDM Precedence Diagram Method

Method PDM is drawn by a rectangular symbol with arrows only as an indication of the relationship between the activities concerned because the location of the activity is in the node section. It is of tencalled AON. The advantage of PDM is that it allows for over lapping relationships (overlapping) that is the next job can be done without having to wait for the previous job (predecessor) to complete 100%, so that in PDM does not recognize the term pseudo activity between two activities that are not requires do not require time and resources (dummy). The disadvantage of this method is that it is more complicated than other methods.

5.4 Critical Path Method

To determine activities that are critical and decisive the critical path can be done using forward calculations and backward calculations. The advantages of knowing: Delaying work on the critical path

causes the entire work to fail projects are delayed in completion. Project completion can be accelerated if the work is available on the critical path it can be accelerated. Supervision or control can be controlled by completing the critical path appropriate solutions and possible trade trade-offstime cost efficiently and program crashes (solved with the optimum time is accelerated with costs also increasing) or shortened time with additional overtime costs. Time slack is found in jobs that are not through the critical path. The downside is that it allows managers to move labor, tools, and costs to jobs on the track critical to be effective and efficient [1].

5.5 RPWM Method

The critical path can be identified from the bar chart obtained from the implementation of RPWM. Scheduling for limited and unlimited resources. Excess in scheduling for unlimited resources, increasing increases the number of resources and will not shorten the project duration. In this case, the resulting project duration is already the shortest. Meanwhile, scheduling for resources is limited, and longer project duration is due to limited resources. Resource allocation and leveling determinations of different project durations for various levels of resource availability. Weaknesses estimated construction costs are an optimal cost for construction that can be obtained based on based on duration or project completion time, overhead costs, allocation, and alignment resources, and costs duet ode lays and related factors.

5.5 Fault Tree Analysis

This method is used for analyzing, displaying, and evaluating failures in a system to provide a mechanism for an effective system at a given level of risk evaluation [26]. This technique is useful for describing and estimating events in a system. This method can able to show possible causes of system failure from several events and various problems. It is easy to read and understand. It lacks uses two main symbols namely event and gate. The fault tree illustrates the relationship between basic events, basic causes of failure, and top events failures that occur are depicted graphically.

5.6 Scurve Method or Hanumm Curve

The S curve is a graph developed by Warren T. Hanumm [22] based on observations of some projects from inception to the end of the project. The S Curve can show the progress of a project based on activities, time, and weight of work presented as a percentage cumulative of all project activities. S curve visualization can provide information about project progress by comparing it against the schedule plan. From here it is known whether there is a delay or acceleration of the scheduled project. These indications can be initial information to take action corrections in the schedule control process. The downside is that the information is not detailed and only limited to assessing project progress. Further improvements are possibly carried out using other methods combined with the block chart method which can be shifted and network planning by updating sources power and time for each activity [6].

5.7 Float

Float is the amount of time available for an activity that allows the delayors low down of such activities in tent ion ally or not deliberate. Excessive project delays do not cause the project to fail and late in solving it. However, this method is less effective and less efficient in completing projects.

5.8 Fuzzy Number Modeling

The approach that is often used to solve optimization problems with several parameters with uncertain values is as follows:

1) Find as uit able model for each problem parameter whose value is uncertain.
2) Transformation of each problem parameter which has an uncertain value becomes a deterministic value.
3) Find a solution for each deterministic parameter and check there sults if there sults. If they are not feasible then repeat Step (2).

Step (1)
This problem uses the L-R flat-type fuzzy number method which is included in the bell curve category [23] proposed by Dubois D. and Prade H. with the following notation:

$$M = \left(ILeft, IRight, \alpha, \beta \right) LR \tag{2}$$

$[ILeft, IRight]$ are the core of the fuzzy number M, with $ILeft$ and $IRight$ being the left (inferior)and right (superior) boundaries of the core interval. Mean while, α and β are on the left side and right side soft the fuzzy number.

The member ship function of this L-R flat flat-type fuzzy number is defined as follows:

$$L\left[(ILeft - x)/\alpha\right] if\ x < ILeft \mu M(x) = 1\ if x \in \left[ILeft, IRight\right] \alpha, \beta \in R + R\left[(x - IRight)/\beta\right]$$

$$if x > IFIRightL[0] = R[0] = 1 and L[1] = R[1] = 0$$

The flat time fuzzy number model with three α-cuts (I=1.0,L=0.6,E=0.2) and five lancer parts (a,b,c,d,e) can simplify this problem.

Alpha Cut

For each $\alpha = I$ and $\mu(x) = I$, x is definite. For every $\alpha = L$ and $_{\mu(x) \geq L}$, x is Worthy. Forany $\alpha = E$ and $_{\mu(x) < E}$, the value of x is ignored.

Step (2)

Each α-cut has a left (inferior) and right (superior) limit that from the three α-cuts, six deterministicreal number values are obtained, namely EKiri, LKiri, IKiri, IKanan, LKiri, and EKiri.

Step (3)

Each value of the six deterministic values is solved in the usual way so that six deterministic solutions are obtained. If the six deterministic solutions are combined, results are obtained in fuzzy number terms.

5.9 Activity Formation Mode

This problem does not include the aspect of diversity of activity for mation modes (one modeo factivity formation).

5.10 Precedence among Activities

The model chosen for the representation of preferences among activities in this problem is AON with the reason that this model is easier to realize in the environments of OOA, OOD, and OOP.A node is represented as an activity object that contains information about the number, name, processor, resource allocation, ready time, duration, deadline time, start time, and finish time. Arcs are represented as connection instances between activity objects whose information is stored in activity successor and predecessor objects.

5.11Minimize Project Make span

The heuristic function chosen to minimize make span in this problem is MINEST, which is based on the smallest EST value.

5.12ProjectSchedulingMethods

There are two project scheduling methods, namely the serial method and the parallel method. The two methods have differences in how they handle resource conflicts. The serial method schedules activities based on their priority order sequentially. The parallel method tries to schedule activities based on their priority order, but if the activity that has a turn at this time cannot be scheduled, then the turn is given to then extpriority order [2].

6. Programming

6.1 Programming Environment

This software is implemented in the Borland C++ Builder programming language version 4.0 which is the development of the C++ language for Windows- based programming environments. This tool provides a VCL class library that supports application programming in graphical displays, and a form designer to creategra phical inter faces easily and quickly [27]. The C++language is a development of the C language equipped with concepts found in the Simula67, Algol 68, and Ad a languages. The concept of class is taken from the Simula 67 language, the concept of operator overloading and placement of declarations between instructions is taken from the Algo l68 language, and the concept of template and exception is taken from the Ada language [28].

6.2 Concept of Class and Object

The concept of classes and objects in C++ aims to create new data types that are identical to the basic data types (int, float, char, string) owned by the language. A basic data type consists of due components, namely a set of bits that represent an abstract value when the basic type is declared and a set of operations that apply to it (for example+,-,*, and /in the float data type). A class consists of a set of data bits (attributes) that state the abstract values of the objects of the class and a set of operations (services) that it has. The concept of class and object can be expressed by analogy as follows Class vs. object≡ typevs. variable [5]. -

6.3 ClassDefinition

A class or object in C++ must be defined like a data structure by changing the struct keyword to class and declared in the header file file_name. h. There are four levels of accessibility for each attribute and service in that class. They are provided by Borland C++ Builder for managing classes that can be used in conjunction with the form designer. This section contains the attributes displayed in the object inspector on the designer form so that they can be manipulated by the designer according to their needs. The attributes in this section are aliases for the attributes in the private section as properties that access these attributes to retrieve or fill in their values.

```
Class TKelas A[:mode_pewarisankelas_yang_divariasi]
{
_published:
                    :
Public
          //constructor,untukmen
    ciptakanobjekdariTKelasATKel
    asA():
          //constructor,untukmemusnahkanobjekdariTKelasA
     -TKelasA():
                    :
                              Protected:
                    :
Private:
                    :
}:
```

Fig. 2. *Definition in Borland C++ Builder.*

7. Implementation

7.1 Implementation of Classes in Software

The classes implemented in this software are distributed in two components, namely the problem domain component and the human inter action component.

7.2 Classes in the Problem Domain Component

The problem domain component consists of 15 classes, namely TJPF, TTabSD, TSb Time, TTabK, TLProfil SD, TL Precedence, TL Alocator SD, TResource, TTime, TKactivities, TProfilSD, TPredence, TAlocatorSD, TElProject, and TBiFuzzy.

7.3 TJPF Class

The TJPF class represents the JPF software problem domain which collects all classes defined in the JPF software problem domain components. This class is instantiated as a member object of the TForm JPF class. The TJPF class also includes other classes that are member objects of this class, namely the TTabSD, TSbTime,and TTabK classes, the TJPF class declaration.

7.4 SectionClass

The container class actsas a container for instantiating objects from the class defined in the section class. This container class consists of the TTabSd, TSbtime, TTabSD,TLProfilSd,TLPredence, and TL Alocation SD classes. The TTabSD class represents a resource table that holds instances of resource objects from

the TS resources class. This class is instantiated as a member object of the TJPF class. TTabSD class declaration. The TSbTime class represents a project scheduling time axis time resource that holds instantiations of time objects from the TTime class. This class is instantiated as a member object of the TJPF class. The TSb Time class declaration.

7.5 Input Data Display Screen Renderer Class

The T form Input class provides input data from the keyboard. Input data validation is filtered through object instantiation of the TM ask Edit class. Information about the rendering state of the rendered screen is constructed by the object instance of the TLabel class. The OK and Cancel buttons are Matched by object in stances of the TBitBtn class. Class TM ask Edit. TLabel and TBitBtn are provided by Borl and C++ Builder. Class declaration TForm Input.

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7.8 Input Data Display Screen Renderer Class

The Tform Input class provides input data from the keyboard. Input data validation is filtered through object instantiation of the TMask Edit class. Information about the rendering state of the rendered screen is constructed by the object instance of the TLabel class. The OK and Cancel buttons are matched by object instances of the TBit Btn class. Class TMask Edit. TLabel and TBit Btnare provided by Borl and C++ Builder. Fig. 3 represents the Class declaration TForm Input.

```
//.....
---
//                                    DEKLARASIKELAST FormMasukan
//.....
---
Class TForm Masukan : public
TForm(
        _published:          //IDE-managed
        Components TBit Btnpan*BitBtn1
        TBit Btnpan* BitBtn2T
        MaskEdit*MaskEdit1;T
        Label*Label;

        Void_fastcall Tampil (TObject*Sender)
        Void_fastcalltutup (TObject*Sender,TCloseAction&Action)

Public:      //User declarations
//.....
---
//                                    CONSTRUKTO
//.....
---
        _fastcall TForm Masukan (TComponent*Owner):

//.....
---
//                                    SETDATAMASUKAN
//.....
---
        Voidmasukan (String, string, string, string):

Protected:          //User declarations
Privatec:    //User declarations

};
//.....
---
Extern PACKAGET Form Masukan*Form Masukan;
//.....
```

Fig.3.*Class Declaration T form Input.*

8. Testing Program and Results

Software testing is based on object-oriented testing rules because it is adapted to the methods used at the analysis and design stages [12].

8.1 Object-directed Tests

The test must be carried out in OOT [Pre-97] namely:

1) Testing is based on aspects of correctness and consistency.
2) Unit testing and integrated testing
3) Testing with test cases

8.2 Truth and Consistency Test

Correctness and consistency tests are carried out on the results of object-oriented analysis and design. The correctness aspect includes writing syntax rules and semantic rules. Software analysis and design uses notation and writing syntax based on object-oriented analysis and design methods. Semantic correctness is determined based on the suitability between the results of analysis and design with software requirements specifications. The consistency aspect is related to testing the message connection between classes. Consistency checking uses the CRC model in the form of a CRC index card. Each card contains the class name responsibility for class services, and collaboration with other classes that send messages to request services from this class.

8.3 Truth Test Results

The method that will be used for the analysis and design of object-oriented models is the [Coad and Yourdon-90] method. Test semantic correctness by comparing the model from the analysis and design results with the soft ware requirements specifications. Table 4 represents the test result of the software.

Table 4. *Software Sematic Test Results.*

No	Requirement Specifications	Model
1	JPF software problem domain	TJPF
2	Resource Table	TTabSD
3	Time axis of project scheduling	TSbWaktu
4	Activity Table	TTabK
5	List of resource usage profiles	TLProfilSD
6	Within the project implementation timespan	TLPresedensi
7	List of successors and list of predecessors of activities	TLAlokasiSD
8	On the activity network	TSumberDaya
9	List of resource allocations for an activity	TWaktu
10	Resource	TKegiatan
11	Fuzzy time parameter names and values	TProfilSD
12	Activity	TPresedensi
13	Resource usage profile on	TAlokatorSD
14	An activity within a certain time	TElProyek
15	Successors and predecessors of activities in the activity network	TBIlFuzzy
16	Allocation of resources to an activity	TForm JPF
17	Project elements	TForm TabSD
18	Fuzzy time parameters	TForm TabK
19	JPF software main test screen interface	TForm ProfilSD
20	Resource table presentation screen interface	TForm AlokasiSD
21	The screen interfaced plays the activity table	TForm WktFuzzy
22	The screen interface displays a graphic profile of Resource use in an activity within the project implementation timespan	TForm JarK
23	The screen interfaced plays resource allocation Graphs for an activity	TForm MSpan
24	The screen interface displays fuzzy number graphics That represents fuzzy time parameters	TForm Gantt
25	Activity network graph display screen interface (implementation not yet completed)	TForm Masukan

8.4 Consistency Test Results

Test the consistency of the model from the results of the analysis and design using the CRC Index Card. Table 5 represents the CRC and TJPF Index Card.

Table 5. *CRC and TJPF Index Card.*

Name Class TJPF		
	Derivate From	
No	Responsibility	Collaborators
1	Constructor	T Form JPF
2	Destructor	T Form JPF
3	Tambah SD	T Form JPF
4	Tambah K	T Form JPF
5	Metode Serial	T Form JPF
6	Metode Parallel	T Form JPF

8.5 Class Test Results

The test examines each service (procedure or function) in a class randomly based on the initial state and final state. If the initial state of a service on a class is known, then test conditions are created based on its initial state. Borland C++ Builder provides an exception and handler command block to check the success/failure of the execution of program code instructions. This command block is inserted in the service code section to check the success/failure of executing that service. Fig. 4 represents the Class Teston MSerial Click and MParallel Click Services.

```
void_fastcallTFormJPF:: MSerial1Click
(TObject*Sender)(
    Try
{
                If(!JPF→Enable)
                deleteJPF;JPF =
                newTJPF;
                BacaTabSD ( )
                ;BacaTabK ( )
                ;JPF→MetodeS
                erial();
                tampilkanHasil
                ();JPF→Enable
                =files ;
    }
    Catch (std;;bab_alloc)
    {
        Showmessage (*Alokasigagal!*) ;
     }
}
//
void_fastcall TForm
JPF::MParaleel1Click(TObject*Sender)(
    Try
{
                If(!JPF→Enable)
                delete JPF;JPF =
                new TJPF;
                Baca TabSD ( )
                ;Baca TabK ( )
                ;JPF→MetodeP
                aralel ( ) ;
                tampilkan
                Hasil
                (); JPF→Enable
                =files ;
    }
    Catch (std;;bab_alloc)
    {
```

Fig.4. *Class Test on M Serial Click and M Parallel Click Services.*

8.6 Integrated Test Results

Integrated tests examine each service in all classes and the relationship between services in one class and services in other classes. Integrated test results are determined based on changes in status and attribute values in related classes. The software classes are related. The classes in this JPF software have functioned according to the requirement specifications.

8.7 Test for Correctness and Consistency

Correctness and consistency tests are carried out on the results of object-oriented analysis and design. Based on the analysis of the project scheduling output from JPF software which is presented in a fuzzy Gantt Chart graphical representation, each activity in fuzzy project scheduling must be scheduled with an optimistic degree greater than or equal to the optimistic degree of its predecessor.

9. Discussion

Integrated tests examine each service in all classes and the relationship between services in one class and services in other classes. Integrated test results are determined based on changes in status and attribute values in related classes. The software classes are related. The classes in this JPF software have functioned according to the requirement specifications. The analysis and design of this JPF software use the OOA and OOD methods from Peter Coad and Edward Yourdon [24].

9.1 Object-oriented analysis

OOA aims to define the problem domain and system responsibility based on the software requirements specification in the problem description, consisting of the following five stages [9]:

- Define classes & objects
- Structure identification
- Subject identification
- Define sat tributes and instance connections between the attributes
- Define services and message connections between services.

If viewed based on the level of detail of the analysis, the OOA model consists of five layers which describe the level of detail of the analysis in stages as follows:

- **Subject**: The subject layer divides the complex problem domain in to several simpler sub-problems.
- **Class & object layers:** The details of classes and objects within each subject that have been defined in the subject layer.
- **Layer structure:** The details are the structural relationships between classes and objects.
- **Attribute layers:** The attributes for each class and object.
- **Service layer:** It details the services for each class and object.

9.2 Class and Object Determination

According to the requirements specification for the JPF software that will be built in this paper at the stage of determining the class& objects in the problem domain, classes & objects are obtained as follows:

- The TJPF class represents the JPF soft ware problem domain.
- Class TTabSD represents the source table.
- The TSbTime class represents the projects cheduling timeax is.
- Class TTabK represents a table of activities.
- The TLProfil SD class represents a list of resource us age profiles in an activity within the project implementation time frame.

The Predence TL class represents the successor list and activity predecessor list in the activity network.

- Class TLAlocatorSD represents a list of resource allocations in an activity.
- Class TRe source represents a resource.
- Class TTimere presents the name and value of the fuzzy time parameter.
- Class Activity represents activity.
- Class TProfil SD represents a profile of resource usage in an activity at acertain time.
- Predenceclassesrepresentsuccessorsandpredecessorsofactivitiesintheactivitynetwork.
- The TAlocator SD class represents the allocation of resources to an activity.
- The TElPr oject SD class represents the project elements.
- Class TBil Fuzzyre presents fuzzy time parameters.

The TJPF class acts as a collector of all classes defined in the domain of the Fuzzy Project Schedule software problem. Persistent classes, including TRe sources, TTime, TActivities, TProfilSD, TPresedence, and TALocator SD. Container classes of type list act as containers for instantiating objects from persistent classes, including TTabSD, TSbTime, TTabK, TLProfilSD, TLPresedensi, and TLAlocator SD.

The classes TTabSD, TSb Time, TTabK, TLProfile SD, TLPrecedence, and TLAlocator SD act as container classes for the classes TResource, TTime, TActivity,TProfileSD,TPresedebsi, and TAlocatorSD. The Tel Project class is an abstract base class for the TResource, TTime, and TActivity classes.

9.3 Defining Attributes and Connection Instances

Defining attributes will describe the stages of analysis to the level of detail of the data structure for each class and the connection instance describes the relationship between class attributes. Connection in stance scan exist between one class and another class or with the class itself.

9.4 Defining Services and Message Connections

The service definition describes the stages of analysis down to the level of detail of the service functions for each class and the message connection describes the message relationship between class services. Message connections exist between one class and another class.

9.5 Object-Directed Design

OOD aims to develop a complete system [8] including:

- Problem Domain Components
- Human Interaction Component
- Task Management Components
- Data Management Components

Table 3. *Comparison of Serial and Parallel Methods with PDM and RPWM*

No	Comparison Parameters	Method			
		Serial	**Parallel**	**PDM**	**RPWM**
1	Critical path	It can be known from the work items.	It is known from the work items	It can be known from The work items	Not visible, TK displays weight work
2	Dependency relationship between activities	Depend ency relationship	Dependency relationship	Using 4 Types of dependency relationship	The dependency relationship Finish to Start was only once.
3	Activity barriers activity	Does not display. There are obstacles to each activityes.	Does not display there are obstacles to each activity.	Does not display there are obstacles to each activity.	Doesn't show any obstacles to each activity.
4	Use of methods	Suitable for use	Suitable for use	Suitable for use projects with activities overlapping	Suitable for building projects graded
5	Types of calculations	Using type weight calculation of every activity.	Using type weight calculation of every activity.	Using calculations for forward and backward.	Using type weight calculation of every activity

10. Advantages and Disadvantages

Advantage

- Object-oriented test results discuss all test results that have been carried out on the design and implementation of JPF software based on the object-oriented testing approach.
- Testing of the model from the results of analysis and design includes correctness aspects and consistency aspects.
- The method that will be used for the analysis and design of object-oriented models is the Coad and Your don method. The results of the analysis and design are shown: if viewed from the correct aspect of the notation and writing syn-index based on the OOA and OOD rules [CoY-91-1, CoY-91-2], then this model has passed the correctness aspect test.

Disadvantage

The disadvantage is that it is less effective and efficient because it takes a very long time to experiment, resulting in large costs and inflated costs.

11. Conclusion

Analysis of the output of the resource usage profile from this software which is presented in a graphical representation, shows that resources can be used optimally, especially for the non-renewable resource category. For the development of this software, the aspect of optimizing resource use can be included as one of the criteria to be achieved. Analysis of the output of project scheduling from this software can be presented in a fuzzy Gantt Chart graphical representation so that it can be concluded that each activity in fuzzy project scheduling must be scheduled with an optimistic degree greater than or equal to the optimistic degree of its precursor.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

References

[1] S. N. S. Sidabutar, M. Amin and Putri, "A Scheduling Production Machine Operations Using the Cds (Campbell Dudek Smith) Method", At Pt Tjokro Bersaudara B, 2020.

[2] K.S., N. O., "Production Scheduling of Retreaded Tires Using the Branch And Bound Method And Campbell Dudeck Smith At Cv", New Nuance. Valtech Journal, vol. 2, no. 2, pp. 108–116, 2019.

[3] A. Latief, P. F. Melu, I. H. Lahay and H. Hasanuddin, "Measuring EmployeeWorkingTimeInCrystalIcePackagingUsingTheTimeStudyMethod", Jambura Industrial Review (Jirev), vol. 1, no. 2, pp. 48–57, 2021.

[4] C. Mashuri, A. H. Mujianto, H. Sucipto and R. Y. Arsam, "Penerapan Algoritma Campbell Dudek Smith (CDS) untuk Optimasi Waktu Produksi Pada Penjadwalan Produksi," Jurnal Sistem Informasi Bisnis, vol. 10, no. 2, pp. 131-136, Nov. 2020.

[5] M. Sholeh, E. W. Asihand I. Sodikin, "Penjadwalan Pekerjaan Yang Optimal Untuk Meminimasi Keterlambatan Pada Pt Mandiri Jogja Internasional", Jurnal Rekavasi, vol. 9, no. 1, pp.35-42, 2021.

[6] T. Nuryawan and T. Dwiwinarno, "Standard Time Measurement for Achieving Productivity Case Study of Making Elementary School Uniforms at Cv", Focus Production Tamansari, Kalasan, Sleman. Effective Journal Of Economics And Business, vol. 11, no. 2, pp. 133–144, 2020.

[7] A. Pranata, "Pemrograman Borland Delphi, Andi Offset, Yogyakarta", 2017.

[8] R. J. Pressman, " Software Engineering A Practitioner Approach", Mc Graw Hill, London, 2017.

[9] A.Y. Pradana and F. Pulansari, "Analisis pengukuran waktu kerja dengan stopwatch time study untuk meningkatkan target produksi di PT", XYZ. JUMINTEN, vol. 2, no. 1, pp.13-24, 2021.

[10] M. Rahayu and S. Juhara, "Measuring Pen Assembling Standard Time Using Downtime Clocks During Work Design Analysis Practicum", Education and Industrial Applications (Unistek), vol. 7, no. 2, pp. 93–97, 2020.

[11] E. M. Sari andM. M. Darmawan, "Measurement of Standard Time And WorkloadAnalysisInTheFillingAndPackingProcessOfLulurMandiProductsAtPt.GloriaOrigita Cosmetics", Asiimetrik Journal: Scientific Journal Of Engineering & Innovation, vol. 51–61,2020.

[12] P. M. Sari, "Proposed Production Scheduling with The Dudek Smith CampbellMethod For Personal Care Products At Pt. Lf Beauty Manufacturing Indonesia", Journal Of Industrial Engineering Optimization (Joti), vol. 2, no. 2, pp. 60–65, 2020.

[13] E. L. Demeulemeester and W. S. Herroelen, "Project scheduling: a research handbook," Springer Science & Business Media, vol. 49, 2006.

[14] D. E. Ezell, "An Analysis of the Program Evaluation and Review Technique (PERT) as a Research and Development Management Tool", American University., 1968.

[15] M. N. Islam, "Crashing project time with least cost: A linear programming approach", Available at SSRN 1012525, 2004.

[16] M. Rondhi, P. A. Pratiwi, V. T. Handini, A. F. Sunartomo and S. A. Budiman, "Agricultural land conversion, land economic value, and sustainable agriculture: A case study in East Java, Indonesia", Land, vol. 7, no. 4, pp.148, 2018.

[17] S. M. Pasaribu and J. K. Routray, "Performance of farmer-managed irrigation systems for rice production in East Java Province, Indonesia", International Journal of Water Resources Development, vol. 21, no. 3, pp.473-491, 2005.

[18] S. C. Sharma, "Operation Research: Pert, Cpm & cost analysis", Discovery Publishing House, 2006.

[19] K. D. Rao, H. S. Kushwaha, A. K. Vermaand and A. Srividya, "Epistemic uncertainty propagation in reliability assessment of complex systems", International Journal of Performability Engineering, vol. 4, no. 1, pp.71, 2008.

[20] L. A. Zadeh, "Fuzzy logic—a personal perspective", Fuzzy sets and systems, vol. 281, pp.4-20, 2015.

[21] G. J. Klir and T. A. Folger, "Fuzzy Sets, Uncertainty, and Information", 1988.

[22] M. Z. Muttaqinand and F. Hardaningrum, "Analysis Of Project Implementation Schedule Using Microsoft Project (Case Study: Trenggalek City Square Area)", IJEEIT: International Journal of Electrical Engineering and Information Technology, vol. 2, no. 1, pp.25-32,2019.

[23] K. M. Sagayam, K. Salahddine, A. A. Elngar and H. M. Ali, "Project Delivery of Goods With Limited Resources and Minimum Time Using Fuzzy Logic Method" Turkish Journal of Computer and Mathematics Education, vol. 12, no. 6, pp.1729-1740, 2021.

[24] P. Coad, E. Yourdonand P. Coad, "Object-oriented analysis", Englewood Cliffs, NJ: Yourdon Press, vol. 2, 1991.

[25] K.Paryati, K.Salahddine, A.A. Elngar and H. M.Ali, "Project Delivery of Goods With Limited Resources and Minimum Time Using Fuzzy Logic Method".

[26] D. Avianda, Y. Yuniatiand Y. Yuniar, "Strategi Peningkatan Produktivitas di Lantai Produksi Menggunak an Metode Objective Matrix", Reka Integra, Vol. 1, no. 4, 2013.

[27] R. Kirwan, J. Che, W.J. Leand S. Sarin, "A Visualization and Analysis tool for VCL Auto-generation Code Framework", In 2021 IEEE International Conference on Service Operations and Logistics, and Informatics (SOLI) (pp. 1-5). IEEE, Dec. 2021.

[28] R.W. Sebesta, "Concepts of programming languages", Pearson Education, Inc, 2012.