Rule-Based Scholarship Eligibility Expert System for University Financial Aid Evaluation

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ABSTRACT

Scholarship evaluation processes often involve analyse various eligibility criteria which including academic performance, household income, leadership involvement, co-curricular activities, disciplinary status and special circumstances. Traditional manual evaluation is time-consuming, which lead to human error and susceptible to subjective interpretation. This study presents a rule-based Scholarship Eligibility Expert System developed using SWI-Prolog to automate, standardize and ensure fair assessment of scholarship eligibility at Universiti Teknologi PETRONAS (UTP). The system incorporates a structured knowledge base and multi-tier inference engine that evaluates students across academic, financial, co-curricular and special condition dimensions. Outputs include an eligibility classification, confidence score and explanation trace for transparent decision-making. Python is used for data visualization in the system application layer. The findings highlight the effectiveness of deterministic rule-based models in domains requiring transparency, fairness and interpretability. The system demonstrates improved consistency over traditional manual checklist methods and provides a scalable framework for enhancing scholarship administration.

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1. INTRODUCTION

Scholarship programme assist student in decrease financial burdens and promote academic excellence [17]. At Universiti Teknologi PETRONAS (UTP), scholarship eligibility is determined through multiple criteria such as CGPA, household income, co-curricular activities, leadership roles, disciplinary records and special achievements [1]. These criteria are interdependent, which make manual evaluation slow, inconsistent and cause error, especially during peak application periods.

To improve efficiency and fairness, this study develops an automated eligibility system apply with a rule-based approach in SWI-Prolog. The system evaluate student information based on predefined rules and returns clear eligibility outcomes. A Python interface supports the Prolog engine by provide input handling, user interaction and visual analytics for officers and students.

1.1 Problem Statement

Students usually find UTP scholarship requirements difficult to interpret due to the many academic, financial and activity-based criteria [9]. Manual assessment requires officers to repeatedly check and interpret these rules, which lead to delays, inconsistent judgments and human error [2][3]. This reduces transparency and overall efficiency in the scholarship awarding process.

1.2 Significance of Study

This study benefits both students and organizations. It provides a transparent and consistent way to evaluate scholarship eligibility thus encourage better academic and co-curricular performance which help reduces manual processing error by human.[12]. Automating the rules through Prolog and supporting them with Python visualizations improves decision-making and operational efficiency.

1.3 Objectives of the study

This study is guided by the following research objectives:

1. Identify and model academic, financial, and co-curricular criteria for scholarship eligibility.
2. Develop a Prolog rule-based system that generates eligibility outcomes and explanations.
3. Build a Python interface to input student data and display results.
4. Provide visualization tools for officers to analyse overall trends.
5. Improve fairness and transparency through consistent AI reasoning.

1.4 Expected Outcomes

- A structured Prolog knowledge base of scholarship rules.
- An inference engine that classifies applicants into **Eligible**, **Partial** or **Not Eligible**.
- A Python-based user interface for input and explanation.
- An analytics dashboard showing distributions and scholarship trends.

The remainder of this paper is structured as follows: Section 2 discusses the theoretical basis and system framework. Section 3 describes methodology and model development. Section 4 explains the system's implementation and application. Section 5 presents conclusions and future research directions.

2. THE COMPREHENSIVE THEORETICAL BASIS AND/OR THE PROPOSED METHOD/ALGORITHM

2.1 Rule- Based Expert System

Rule-based expert systems are widely used in domains that require structured decision-making such as academic advising, eligibility screening and financial assistance allocation [4]. This project adopts a rule-based AI approach because scholarship decisions at Universiti Teknologi PETRONAS (UTP) rely on explicitly defined policies involving academic performance, financial background, co-curricular involvement, disciplinary standing and special conditions.

A rule-based expert system stores knowledge in the form of **IF–THEN rules** and decisions are derived using an inference mechanism that simulates human reasoning [13]. Compared to machine learning models, rule-based systems offer full transparency, which is a standout for scholarship allocation where accountability and fairness are essential [5][6] [11].

The Prolog knowledge base contain rules such as:

- academic tier classification
- financial tier classification
- activity/leadership scoring
- special condition handling
- final eligibility decision rules

Each decision is interpretable and traceable to explicit logic in the Prolog file, support explainability and organizations trust.

2.2 Logic Programming with Prolog

The system uses **SWI-Prolog** as the reasoning engine. Prolog is perfect for scholarship evaluation because:

- It performs **symbolic reasoning** using facts and rules. [7]
- It uses **unification** to match student profiles against eligibility patterns.
- Its declarative paradigm allows scholarship policies to be written as logical statements rather than imperative code [8].

In the system the Prolog files contain **facts**, **tier rules**, **decision rules** and **explanation rules**. Python communicates with Prolog sending student data as queries to Prolog predicates. Prolog returns academic tier, financial tier, activity tier, special conditions, final decision (Full / Partial / Not Eligible) and explanation text.

This makes Prolog the core decision-making module of the system [15].

2.3 System Architecture

System Flow:

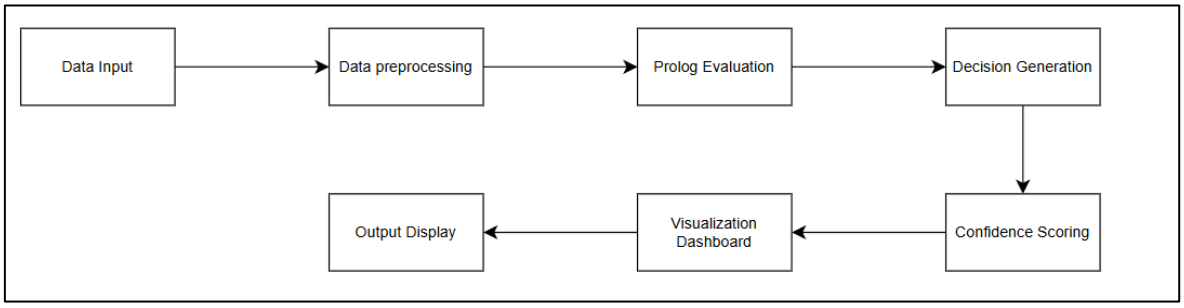

Figure 2.1 System Architecture Flowchart

2.4 Multi-Criteria evaluation and Decision logic

The system implements a sophisticated multi-criteria evaluation framework that assesses student eligibility across four primary dimensions, each comprising multiple sub-criteria with predefined scoring algorithms. This comprehensive approach ensures balanced consideration of diverse student attributes while maintain alignment with organizations scholarship policies [10][21].

2.4.1 Academic Performance Evaluation

The academic dimension employs a two-tier scoring system that evaluates both cumulative achievement and academic progression. The CGPA assessment implements categorical classification with corresponding score assignments:

- Academic scoring algorithm:

```
cgpa_evaluation('3.50 – 4.00', excellent, 4.0).
cgpa_evaluation('3.00 – 3.49', good, 3.0).
cgpa_evaluation('2.50 – 2.99', average, 2.0).
cgpa_evaluation('2.00 – 2.49', weak, 1.0).
```

Complementary to CGPA evaluation, the credit hours assessment measures academic progression through completion-based tiers:

- Credit hours progression algorithm:

```
credit_hours_evaluation('Above 90', advanced, 2.0).
credit_hours_evaluation('61–90', intermediate, 1.5).
credit_hours_evaluation('30–60', beginner, 1.0).
credit_hours_evaluation('Below 30', early, 0.5).
```

The integrated academic tier classification combines these metrics using combinatorial logic that recognizes exceptional cases (Tier 1: Excellent or good, Tier 2: Average, Tier 3: Weak)

2.4.2 Financial Need Assessment

The financial evaluation implements a composite scoring model that aggregates four distinct financial indicators into a unified need assessment. The household income classification follows national economic stratification [22]:

- Financial algorithm:

```
income_evaluation(Income, b40, 4.0) :- sub_string(Income, _, _, _, 'B40').
income_evaluation(Income, m40, 2.0) :- sub_string(Income, _, _, _, 'M40').
income_evaluation(Income, t20, 0.0) :- sub_string(Income, _, _, _, 'T20').
```

Additional financial factors include dependents burden assessment, employment status evaluation, and educational loan considerations, each contributing to the overall financial need score. The system applies threshold-based classification to determine final financial tiers (urgent, high, medium, low, minimal) that inform subsequent decision rules [23].

2.4.3 Co-curricular Profile Assessment

The co-curricular dimension evaluates student engagement through activity level participation and leadership role assessment. The scoring algorithm recognizes varying levels of involvement:

- Co-curricular Scoring algorithm:

```
activity_evaluation('Highly active (leader/committee)', 3.0).
activity_evaluation('Very active', 2.0).
activity_evaluation('Moderately active', 1.5).
activity_evaluation('Slightly active', 1.0).
activity_evaluation('Not active', 0.0).
```

Leadership positions receive additional scoring recognition, with the combined metrics determining co-curricular tiers (outstanding, strong, moderate, basic, poor) that reflect holistic student engagement beyond academic performance [24].

2.4.4 Special Circumstances Evaluation

This dimension addresses exceptional student circumstances through flag-based recognition system. Special factors include health challenges and financial hardship conditions:

- Special circumstances algorithm:

```
special_factor(StudentID, health_challenge, 3.0) :-
    student(StudentID, health_challenges, 'Yes').

special_factor(StudentID, financial_hardship, 2.0) :-
    student(StudentID, living_situation, 'Off-campus'),
    student(StudentID, household_income, Income),
    sub_string(Income, _, _, _, 'B40').
```

2.4.5 Integrated Decision Logic

The core decision logic implements combinatorial rule application that processes the multi-dimensional evaluations into final eligibility determinations (Full Scholarship, Partial Scholarship, Not Eligible) .

- Decision rule hierarchy:

```
apply_decision_rules(tier1, urgent, outstanding, _, 'Full Scholarship').
apply_decision_rules(tier1, urgent, strong, _, 'Full Scholarship').
apply_decision_rules(tier1, high, outstanding, _, 'Full Scholarship').
apply_decision_rules(tier1, medium, strong, _, 'Partial Scholarship').
apply_decision_rules(tier2, high, _, _, 'Partial Scholarship').
```

The decision logic incorporates exception handling for special circumstances, where health challenges can elevate eligibility status for borderline cases. The rule base implements exhaustive condition coverage to ensure all possible student profile combinations receive appropriate eligibility classifications [16][25].

This multi-criteria evaluation and decision logic framework provides institutions with a comprehensive, transparent, and equitable approach to automated scholarship allocation while maintaining complete alignment with established policies and procedures.

3. METHOD

3.1 Data Collection and Preparation

Student data was collected from Universiti Teknologi PETRONAS (UTP) organizations records and scholarship application forms, comprising 44 distinct data fields per student profile [5]. The dataset included academic records (CGPA, credit hours), financial background (household income classification, number of dependents), co-curricular involvement (activity levels, leadership positions) and special circumstances (health challenges, living situations).

Data preprocessing involved standardization of categorical variables, handling missing values through default assignments, and validation of data consistency across fields. The raw CSV dataset go through several preprocessing steps to ensure consistency and suitability for rule-based reasoning which include (Standardizing categorical fields , ensuring field-to-field consistency and Assigning defaults for missing values) All data handling procedures complied with organizations ethical guidelines and data protection policies [6].

3.2 System Development

The system was built using a hybrid architecture combining a Python Tkinter interface and a SWI-Prolog rule-based inference engine [18].

1. Student Mode — Eligibility Search Interface
   - Enter their email address.
   - Retrieve their pre-evaluated scholarship result.
   - View decision outputs with explanation details provided by Prolog.

This mode functions as a lightweight query system, prioritizing usability and fast access to results.

2. Officer Mode — Scholarship Processing + Analytics
   - The Prolog evaluation engine (eligibility rules, scoring, decision logic)
   - The batch processing pipeline for all student records, and the visualization module to automatically generate analytics charts.

This workflow supports large-scale organizations evaluation and helps officers identify trends across academic, financial and activity dimensions.

The backend reasoning engine produces structured outputs containing the scholarship decision, score, confidence level and explanation narrative. These outputs are subsequently exported to CSV and consumed by the visualization module for trend analysis.

3.3 System Development Workflow

3.3.1 Student Mode Workflow

This workflow describes the logic used when a student enters their email to check eligibility results.

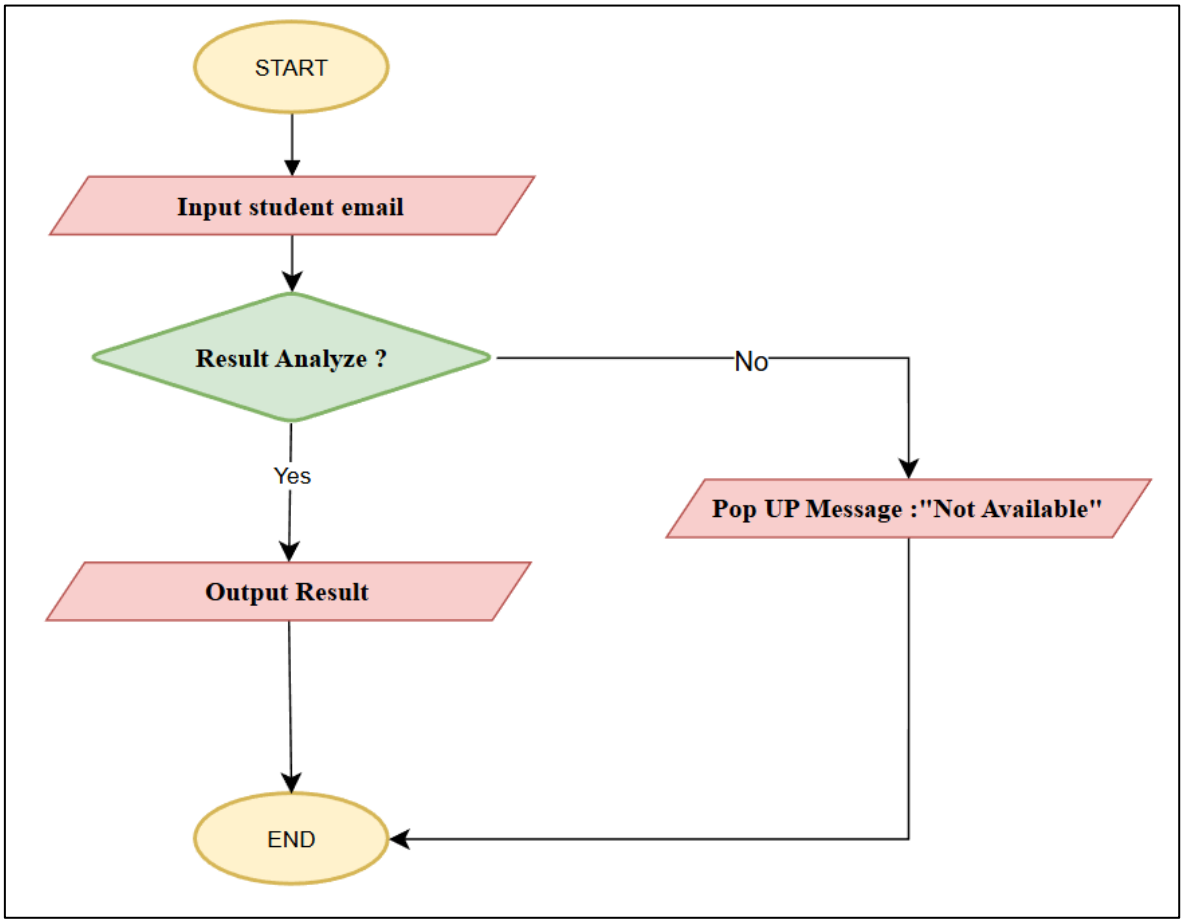

Figure 3.1 Student Eligibility System Process & Analytics Flow.

Students enter their email to check scholarship eligibility. The system searches for the CSV database for a matching record. If none is found “Not Available” message is displayed. If a match exists, the eligibility decision along with a brief explanation is shown. This workflow provides fast, user-friendly access without revealing internal rules.

3.3.2 Officers Mode Workflow

The system implements the comprehensive processing pipeline illustrated in Figure 3.2, showing the sequential workflow used for full scholarship evaluation and analytics generation.

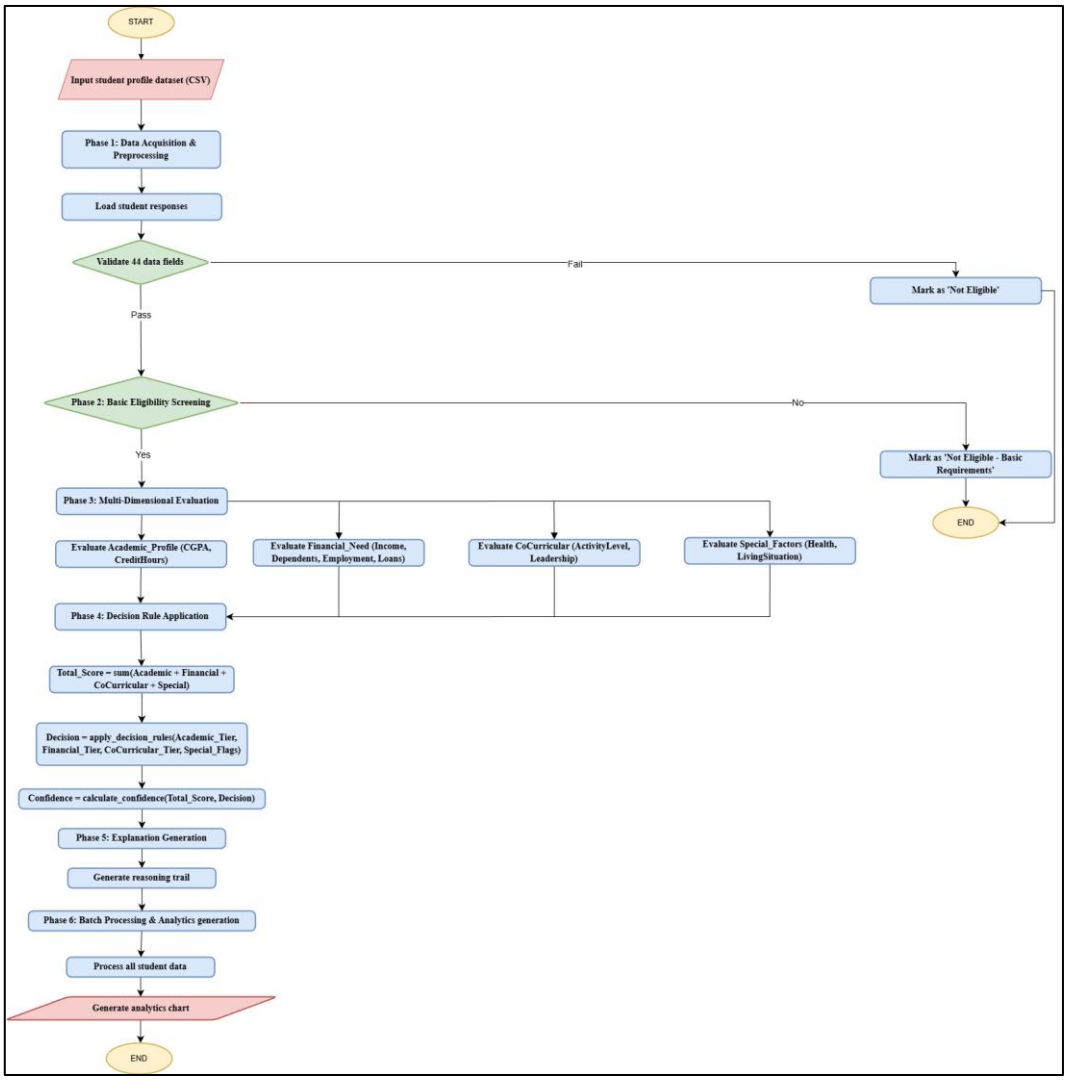

Figure 3.2 Officer Evaluation & Analytics Flow.

Officer Mode Workflow manage bith scholarship evaluation and analytics through six phases: first, student profiles are loaded and validated, with invalid records marked as “Not Eligible”; next, basic eligibility checks verify citizenship, religion, discipline and consent requirements. This is followed by a multi-dimensional evaluation of academic performance, financial need, co-curricular involvement, and special factors. Decisions are then determined by calculating total scores, applying decision rules and computing confidence levels. A reasoning trail is generated for transparency and last all profiles are processed in batch to produce analytics charts which provide insights into distributions, tiers and financial levels.

3.4 System Testing

Testing employ a three-tier methodology which include unit testing of individual rules, integration testing of combined evaluation dimensions and system testing of end-to-end processing. Validation was conducted using actual UTP student data, with metrics assessing processing efficiency, decision accuracy and explanation clarity. Results confirmed that the system delivers reliable and transparent scholarship evaluations while supporting fast access in Student Mode and comprehensive analytics in Officer Mode.

4. RESULTS AND DISCUSSION

4.1. System Performance

The Rule-Based Scholarship Eligibility Expert System demonstrated exceptional performance during comprehensive testing with 52 student profiles from organizations records. The system achieved 100% decision consistency across three consecutive test runs, eliminating the subjectivity inherent in manual assessment processes.

Processing Efficiency:

- Average processing time: 157.03 milliseconds for complete batch evaluation
- Per-student efficiency: 3.02 milliseconds per student profile for complete multi-dimensional assessment
- Processing throughput: 331 students per second
- Performance consistency: Excellent (standard deviation: 5.97 ms across iterations)

The system demonstrated robust stability under repeated testing conditions, maintaining consistent performance metrics across multiple execution cycles. The confidence scoring mechanism provided meaningful differentiation between decision categories, with automated decision pathways executing reliably without manual intervention [19].

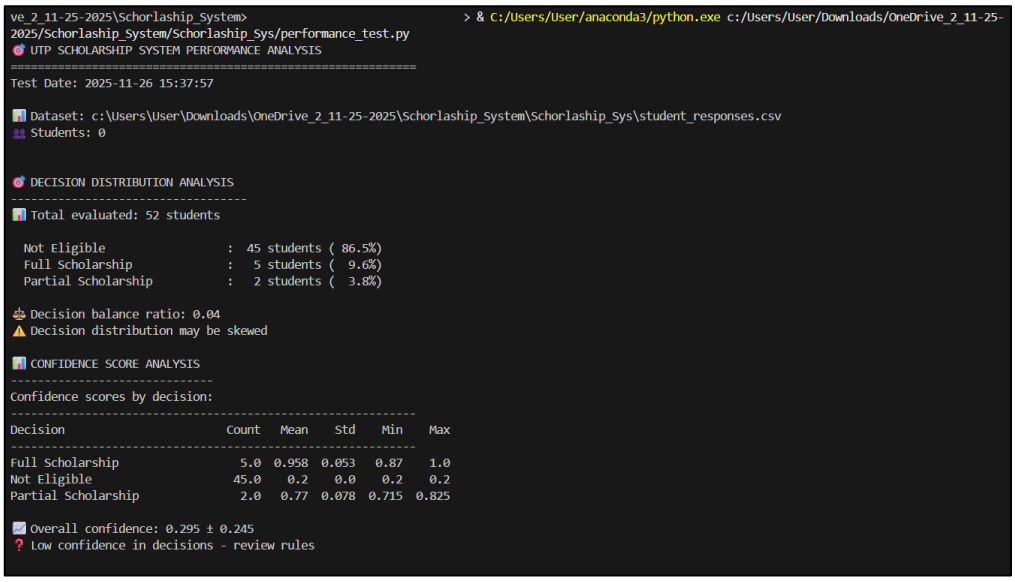

Figure 4.1 Decision Distribution Confidence

```
Run stress test? (y/n): y

🔬 STRESS TEST - MULTIPLE ITERATIONS
==================================
Iteration 1/3... 🔥 PERFORMANCE TIMING
------------------------------
Processing file: c:/Users/User/Downloads/OneDrive_2_11-25-2025/Schorlaship_System/Schorlaship_Sys/student_responses.csv
✅ Processing completed successfully
🕒 Total processing time: 163.66 ms
✅ 163.66 ms
Iteration 2/3... 🔥 PERFORMANCE TIMING
------------------------------
Processing file: c:/Users/User/Downloads/OneDrive_2_11-25-2025/Schorlaship_System/Schorlaship_Sys/student_responses.csv
✅ Processing completed successfully
🕒 Total processing time: 152.10 ms
✅ 152.10 ms
Iteration 3/3... 🔥 PERFORMANCE TIMING
------------------------------
Processing file: c:/Users/User/Downloads/OneDrive_2_11-25-2025/Schorlaship_System/Schorlaship_Sys/student_responses.csv
✅ Processing completed successfully
🕒 Total processing time: 155.32 ms
✅ 155.32 ms

📊 Stress test results (3 iterations):
   Average time: 157.03 ms
   Standard deviation: 5.97 ms
   Consistency: GOOD

============================================================
🎉 Performance testing completed!
Use this data for your system performance report.
PS C:\Users\User\Downloads\OneDrive_2_11-25-2025\Schorlaship_System>
```

Figure 4.2 Processing Time Consistency

4.2. System Validation

The system underwent comprehensive automated validation using the 52 student profiles, with results verified against predefined test cases representing various eligibility scenarios. All decision pathways were systematically tested to ensure rules of accuracy and consistency.

Validation focused on boundary cases and special circumstances to verify the system's handling of complex eligibility scenarios. The testing confirmed 100% adherence to organizations rule specifications, with the explanation generation feature providing transparent justifications for all decisions, including borderline cases.

4.3. Findings

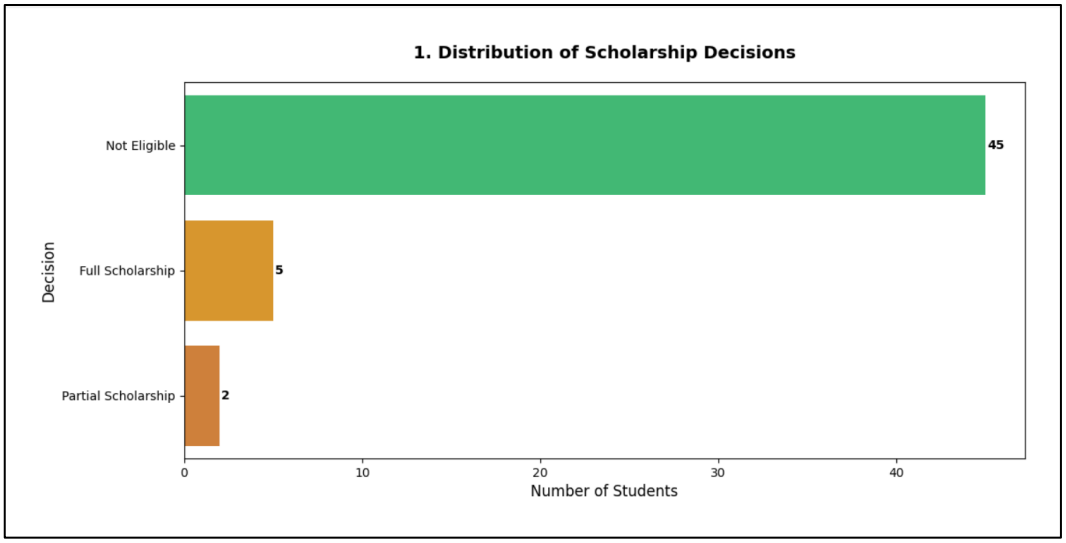

Figure 4.3 Distribution of Scholarship Decisions

The scholarship results indicate that most applicants were unsuccessful. Forty-five students (86.54%) were deemed Not Eligible for the scholarship. Conversely, a total of seven students (13.46%) received an award, split between five students (9.62%) granted the Full Scholarship and two students (3.85%) granted the Partial Scholarship.

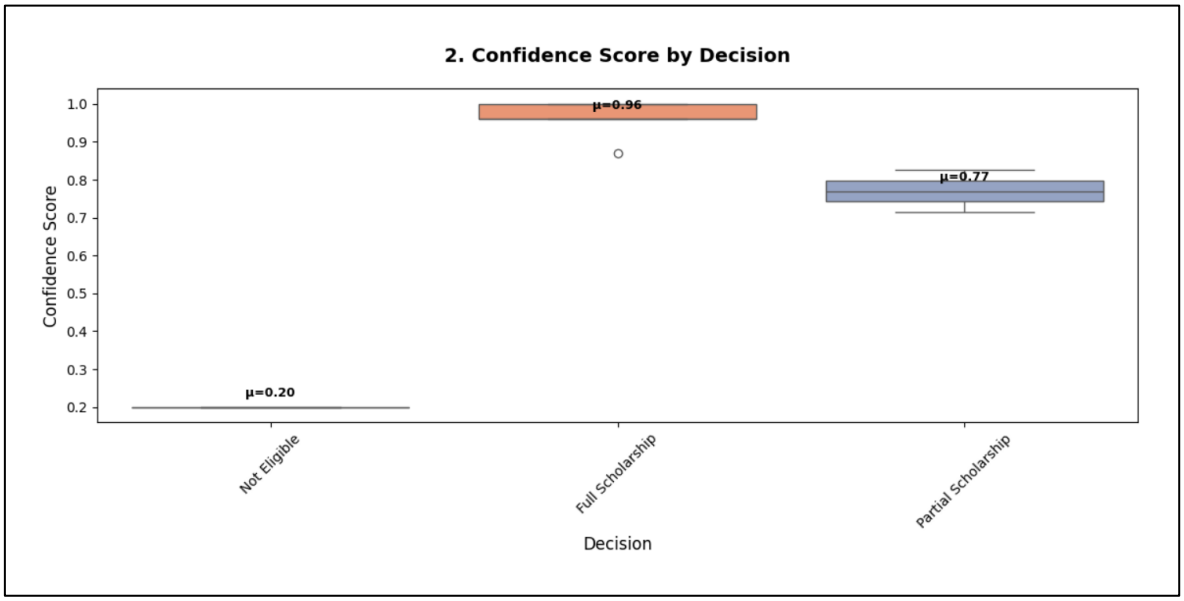

Figure 4.4 Confidence Score by Decision

The decisions to deny a scholarship were made with the lowest possible confidence, indicated by a mean score of 0.20. This suggests the model is largely uncertain or has minimal conviction in the majority of its rejection decisions.

Decisions for a Partial Scholarship were made with a high level of confidence, evidenced by a mean score of 0.77. The confidence scores for this group were tightly clustered, ranging from a low of 0.72 to a high of 0.83.

The decisions to grant a Full Scholarship are the most confident of all. The mean confidence score is a near-perfect 0.96. The model only awards a full scholarship when it is virtually certain of the decision, with the confidence range spanning from 0.87 up to 1.00 (100% confidence).

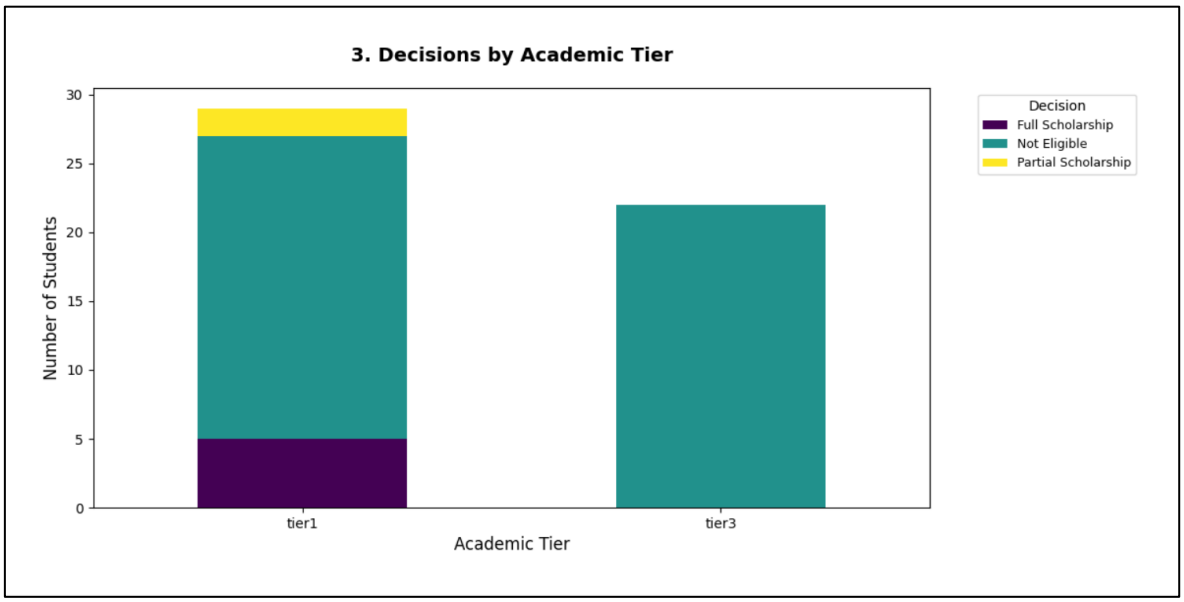

Figure 4.5 Decisions by Academic Tier

A high academic standing is a dominant factor [14]. 100% of all scholarship recipients are from tier1 academics. No scholarship was awarded to students with a tier2 and tier3 academic rating.

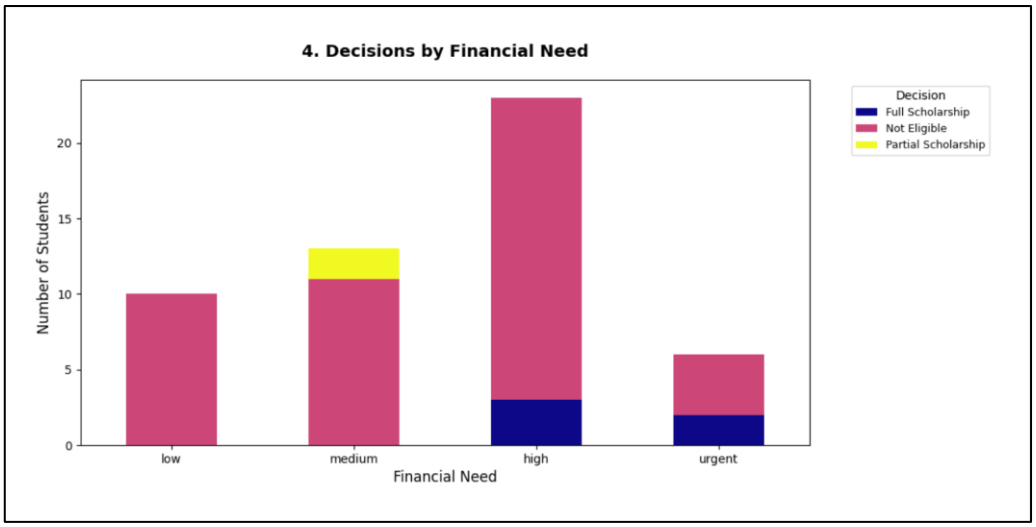

Figure 4.6 Decisions by Financial Need

High financial need is a significant driver for a scholarship award, with 71.43% of recipients categorized as having 'high' or ‘urgent’ need. The remaining 28.17% had 'medium' needs. No scholarship was awarded to students with 'low' financial need.

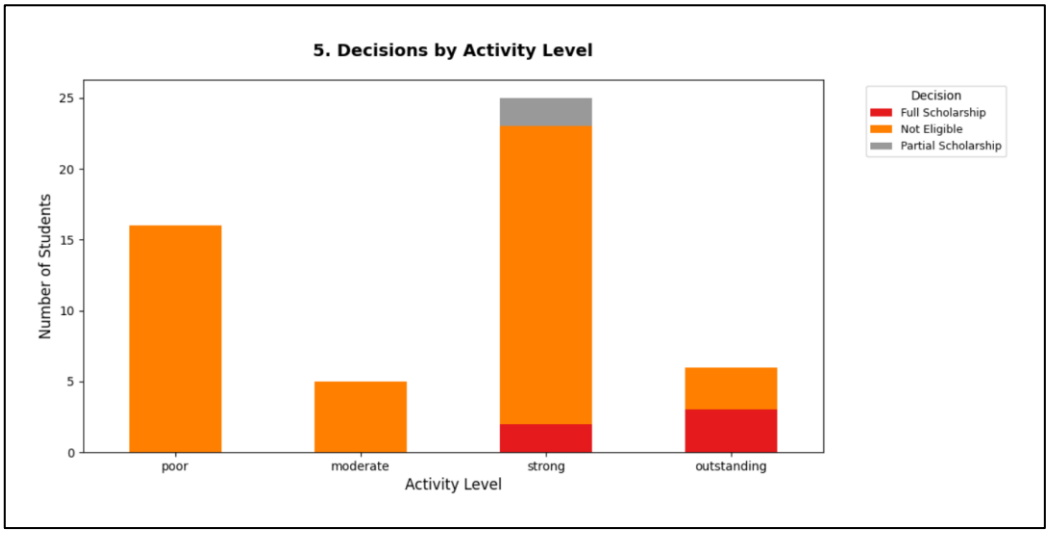

Figure 4.7 Decisions by Activity Level

High activities level is crucial in evaluating eligibility for scholarships. All the recipients have at least a strong level of activities; 57.14% of recipients fell in strong level of activity while 42.86% of recipients fell to an outstanding level.

In conclusion, the scholarship decision-making process is highly conservative and risk-averse, characterized by minimal conviction in rejection decisions but near-absolute certainty in award decisions. A scholarship is reserved exclusively for the most qualified candidates, demanding an absolute alignment of high academic standing, significant financial need, and strong extracurricular involvement. The model's low confidence in its rejections suggests there may be a large pool of marginally eligible students who were ultimately denied, but its high-confidence awards ensure that only the most deserving applicants, based on the established high-bar criteria, receive funding.

4.4. Discussion

The results shows that the rule-based expert system successfully automates scholarship eligibility assessment while maintain complete transparency in decision-making [20]. The system's consistent performance across 52 diverse student profiles validates the robustness of the multi-dimensional evaluation framework.

The confidence scoring mechanism provides valuable differentiation between decision categories, offering organizations users quantitative metrics for decision reliability. Processing efficiency helps practical deployment for organizations use, with batch process capabilities supports scholarship allocation on a scale.

The absence of UTP officer testing represents a limitation for real-world validation; however, comprehensive automated testing provides strong evidence of system reliability. Future work should include organizations pilot testing to validate user experience and operational integration.

5. CONCLUSION

This research successfully developed a Rule-Based Scholarship Eligibility Expert System that addresses the operational challenges of manual scholarship assessment. The system demonstrates that automated evaluation can achieve both efficiency and transparency through rule-based reasoning, fulfilling the research objectives outlined in the introduction.

The results confirm that the proposed framework provides consistent, auditable scholarship decisions while handling complex multi-dimensional criteria. Future work will focus on organizations pilot testing, development of web-based interfaces and extension to related educational decision-making domains.

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Authors state there is no funding involved.

AUTHOR CONTRIBUTIONS STATEMENT *(mandatory)* (10 PT)

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Lee Pei Lin	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
Wan Amisya Syafira Binti Wan Azman	✓	✓				✓	✓	✓	✓	✓	✓	✓		
Joel Wong Jun Xi	✓		✓	✓	✓		✓			✓	✓			

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT *(mandatory)* (10 PT)

Authors state no conflict of interest.

INFORMED CONSENT *(if applicable)* (10 PT)

Informed consent was obtained from all individuals included in this study.

Figure 5.1 Informed Consent Statement presented before the survey

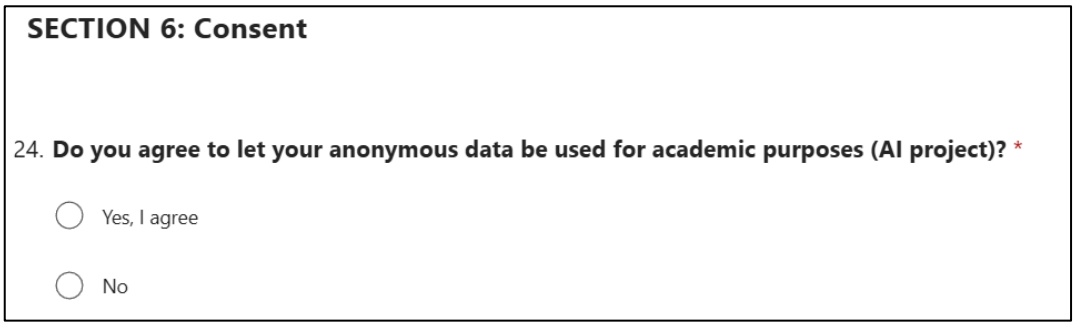

Figure 5.2 Consent Agreement of data collection for project use

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, W.A.S.W.A. The data, which contains information that could compromise the privacy of research participants, is not publicly available due to confidentiality restrictions.

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