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Academic Recommender System Using Engagement Advising and Backward Chaining Model

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Abstract

Background: The goal of academic supervision is to help students plan their academic journey and graduate on time. An intelligent support system is needed to spot potentially struggling students and identify the issues as early as possible.
Objective: This study aims to develop an academic advising recommender system that improves decision-making through system utility, ease of use, and clearly visualized information. The study also aims to find the best advising relationship model to be implemented in the proposed system.
Methods: The system was modeled by following the hybrid approach to obtain information and suggest recommended actions. The recommendation was modeled by backward chaining to prevent students from dropping out.
Results: To validate the recommendations given by the proposed system, we used conformity level, and the result was 94.45%. To evaluate the utility of the system, we used the backbox method, resulting in satisfactory responses. Lastly, to evaluate user acceptance, we used the technology acceptance model (TAM), resulting in 85% ease of use and 91.2% perceived usefulness for the four main features, study planning, graduate timeline simulation, progress report, and visualization of academic KPIs.
Conclusion: We propose an academic recommender system with KPIs visualization and academic planning information.

Keywords: Academic advising model, recommender system, backward chaining, goal-driven, technology acceptance model, certainty factor

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I. INTRODUCTION

Higher education institutions need to ensure that their students succeed academically. Two indicators to measure the institutions' success are student retention and engagement. Student retention is measured from the ratio of student withdrawal, attrition, and drop out [1]. Student engagement can be measured qualitatively by how involved students are in their learning and measured quantitatively from their academic performance [2]. The undergraduate program is built with four domains: the learning process characteristics, the learning planning, the learning implementation, and the learning load. In the learning and planning processes, universities are required to facilitate students with realistic planning and implementation. The learning process is carried out according to the study plan that has been approved by an academic adviser. Students are provided with advice, recommendations and motivation to achieve their academic goal and their long-term plan beyond the academia.

Study planning needs to be supervised carefully to ensure that students can meet their timeline to graduate [3]. However, the supervision is time-consuming and must be based on appropriate data and information. To monitor students' progress, a tool to generate key performance indicators (KPIs) is needed. Past studies have developed methods and approaches to assist the learning process and academic decision-making. This is made possible by the increased volume and types of online information and the improved quality of IT infrastructure. Urdaneta-Ponte et al. stated that the most widely used approach for developing a recommendation system in the field of education is the collaborative, content-based, and hybrid approach [4]. Maphosa et al. also conducted a systematic literature review on studies about recommendation systems for elective courses [5]. Santosa et al. conducted a study to assist the student

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admission process in universities using the KMeans Clustering algorithm with the aim to select the best candidates [6]. Wijanto et al. developed a thesis-supervisor recommender system with representative content and information retrieval [7]. Another study developed a recommendation system using a machine learning algorithm for the final project topics based on student interests and competencies [8].

This study aims to develop an academic advising recommender system that improves decision-making through utility, ease of use, and clear visual information. The study also aims to find the best advising relationship model to be implemented in the proposed system.

II. Methods

This research is conducted in four steps: analyzing the most suitable advising model, acquiring rules and constraints, modeling the system using the backward chaining inference approach, designing the system features and visualization of information, and lastly evaluating the system.

A. Academic Advisory Models

Academic consultation activity in higher education can influence educational outcomes, but its role is often overlooked. Student satisfaction is closely related to the college experience, including educational guidance activities, and student commitment to the study period [9]. However, the study plan tends to be short-term, only made every semester and the overall process may not be optimum. Past research has focused on the development and implementation of an automatic advising system [6] [8] [9] [10]. This study aims to establish an effective recommender system—the collaborative, content-based, or hybrid approaches [5], an appropriate academic counseling model, and the reasoning workflow algorithm of the proposed model.

There are five counseling models (see Table 1). Feghali et al. developed a web-based academic recommender system by adopting an engagement advisory model [10]. In this approach, an adviser assists students in identifying and clarifying academic goals and objectives. Students are expected to have a GPA greater than 2.75, know the list of mandatory and elective courses in each sub-department, know their strengths and weaknesses in the learning process, be proactive in seeking information related to the prospects of the sub-major in the job market, and identify personal priorities in academic and non-academic areas [11]. It can be concluded that this model requires students to be mature and experienced, such as those in postgraduate programs.

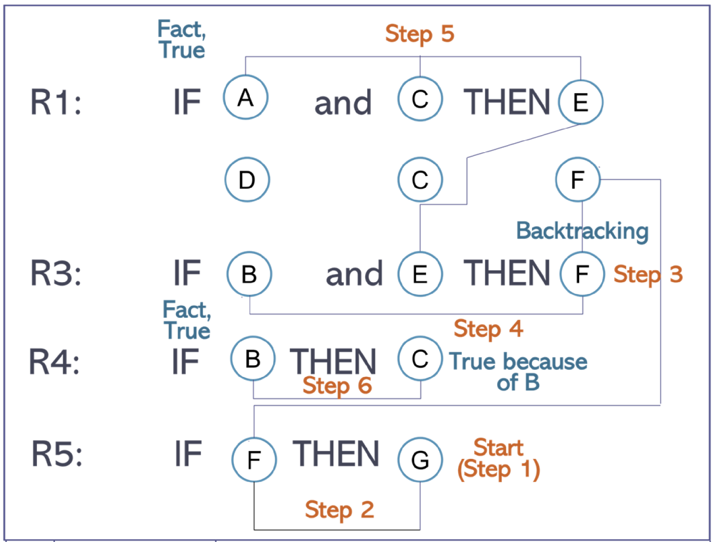
From the analysis of the study planning shown in Fig. 1, the first suggested pattern of interaction is the Developmental Relationship model, where the decision-making of choosing courses are given to students. However, there are no tools that show students' historical data and KPIs, so it is difficult to detect if a student is struggling and what causes it. Therefore, the model should be combined with Intrusive Advising, where adviser is allowed for an intervention that facilitates informed decision making to keep students on track [12]. An Intrusive Advising model will allow an adviser to monitor students' performance and encourage student to be more responsible with their study.

TABLE 1
THE COMPARISON OF ADVISING MODELS BASED ON ROLES AND RESPONSIBILITIES

Relationships Model	Student (Advisee)	Guardian Adviser
Intrusive Advising [10]	Certain students are given more attention from guardian adviser	Give more attention to students who are in an emergency
The Engagement Model [11]	Understand their academic and non-academic performance	guide students to achieve objective targets
Prescriptive Relationship	Follow the directions of the guardian adviser	Fully responsible
Developmental Relationship [12]	Responsible for their study planning	Delegate the responsibility mainly to students
The Integrated Advising	Plan by following the decisions of the guardian adviser	Give responsibility to students but still take full responsibility

B. System Requirement Modeling

The proposed system needs to allow the adviser to monitor courses that the student needs to retake along with the information about the credit points, whether it is a core course or elective, in which semester it is offered, and the prerequisite courses. Because the timeline is also important, the proposed system should also provide KPIs and SMART Goals recommendations, namely specific, measurable, achievable, relevant, and timebound [13] goals. The indication of struggle is based on academic performance (grades D and E), the total credit with grades D and E is more than 12, and they have core courses to retake. To evaluate and monitor student performance, an adviser will need historical information with clear visualization. In designing a visualization, it is necessary to map the relationship between data type and information**Invalid source specified.**. Past studies have developed recommendation systems with different approaches. Bakhshinategh et al. did collaborative filtering [14], and Jiang et al. used neural networks for data-driven systems [15]. Sharma et al. used backward chaining to design an expert system that helps students choose a branch of engineering according to their capabilities [16]. However, these systems need validation by gathering experts' opinions and testing their user-friendliness. Also, these systems are too dependent on advisers' availability. Therefore, in this study, the focus is to make the process more automated.



A	Course need to be taken on respective semester according to curriculum	IF IPS > 3,2 Then max 24 Credits IF IPS > 2,5 and ≤ 3,2 Then max 20 Credits IF IPS > 2,0 and ≤ 2,5 Then max 18 Credits IF IPS ≤ 2,0 Then max 15 Credits OTHER Retake courses for previous semester with max 15 credits
B	Career points	Minimum requirement of each subject
C	GPS (IPS)	Counting iteratively the gap to targeted GPA
D	Course that need to be retaken (D and E)	The maximum courses with index D is 12, and it cant be core course (known from the code course)
E	Credits (SKS)	Counting iteratively on each term (semester) until 144
F	GPA (IPK)	Following graduate target
G	Graduate year	counting iteratively to recommend academic purpose on each semester

Fig. 1. Backward chaining model of the proposed system

The algorithm will follow the reasoning technique commonly used by an adviser when providing academic guidance. The recommender system uses a hybrid approach combining rules from the adviser and inference engine, which generates new output from the known rules and information. Inference with rules implements a heuristic process, which is reflected in the search mechanism. There are two inferencing rules methods, forward chaining (data-driven) and backward chaining (goal-driven). Because the inference of academic plan advising is inductive, meaning students set their academic target and goal rather than moving backward, the goal-driven approach or backward chaining is more appropriate.

The inference model would be built as rules and constraints that apply to the bachelor programs' information systems. Fig. 1 illustrates the steps of the inference system. There are six steps in the proposed system algorithm. It starts with inputting academic performance targets and goals, with the output being the academic target planning for the next semester. Then, each term, the model will be updated using data from the academic transcript from the previous semester. These data are used to calculate the study planning recommendations based on the KPI realization. Four main features provide information for the academic supervision process: study planning, graduation timeline simulation, progress report, and KPI visualization.

In the first and second steps, users will input their target GPA and graduation year, which by default is four years or eight semesters. If students complete their study period in three years and six months, they can complete their study period earlier. The ITHB information systems study program requires a minimum GPA of 2.5 to graduate so the students must meet the minimum GPA to graduate. The output from Step 3 is the GPS, the total credits taken, and the total career points. The system will calculate the total number of credits that have been taken. In Step 4, the gap between the current and the target GPA is calculated, along with the required total credits to graduate. In Step 5, students are given recommendations of courses to retake. The system will search for courses with grades D and E, and map them based on the group of subjects, whether they are core and elective courses and opened in odd or even semesters.

In Step 6, the system provides a simulation for users to cancel a course and its impact on the total credits needed to graduate from the program, the total number of credits with grades D and E and the course code to be retaken, and the number of credits to be taken in each semester. The system recalculates the study period, and the output of the system is a projected length of study and the predicted graduation predicate. In Step 7, the system will provide information on graduate predicate projections. The GPA target will be recalculated every time there is new performance data. The interaction between users and the system and its features is shown in Table 2.

TABLE 2
SYSTEM FEATURES AND OUTPUT INFORMATION

Information	Description	Feature
Core Course	Courses that are currently active or do not have study results yet	Study planning
Elective	Elective courses based on the program's sub-major or students' interests	
Courses to retake	Courses that do not meet graduation standards (minimum C)	
GPA	GPA target	simulation
GPS	GPS in yellow shows that from previous semester there are D grades red shows E grades or more than 12 credits with D grades	progress report and visualization of academic KPIs
Remaining study period	Calculated backward form regular period of four years with a maximum period of seven years	
Total credits	144 SKS	
Students (advisee)	Student ID and the adviser's name	

C. Dataset and System Evaluation

Private universities in Indonesia need more efforts to retain students [17]. In this research, we used student data from the ITHB Department of Information Systems as part of the ongoing quality improvement efforts. Based on current practice, academic advisers provide assistance throughout the academic year. However, there are currently no tools to provide historical information and visualize academic KPIs. A preliminary survey shows that only 43% of students considered study planning an important process. We employed 18 students with various scenarios in the system testing and five lecturers in the evaluation. The students were from classes of 2015 and 2016, who were in the near end period of their academic times. Prior to the survey, all of them received a one-week trial.

The proposed system underwent an evaluation process to ensure users understand the process of using the application in each section [18]. Then, to test the rules in backward chaining, we used the conformity assessment between advisers and the proposed system. Secondly, to evaluate the interaction between the user and the proposed system, we used Technology Acceptance Model (TAM). There are two categories of users based on the level of organizational structure: middle management and lower management [19]. The students and parents are in the low management, while the advisers and the heads of academic programs play a middle management role in checking academic performance and monitoring the academic KPIs. A cognitive assessment is also held to determine which aspects influence the use of the proposed system. This bottom-up evaluation is to ensure that the application is developed based on the user intent

III. RESULT

The system assigns three roles: the student, the adviser, and the head of the academic program. Each student enrolled in the system to get their adviser assigned. The adviser can get information and recommendation for academic progress and graduation timeline target. The proposed system will send an alert for the potentially struggling student based on their academic transcript, in accordance with the rules and constraints to graduates as modeled by the system.

TABLE 3
COMPARATION OF RECOMMENDATION RESULT AS THE CONFORMITY LEVEL

Recommendation	**Case**	**Expert Decision**					
		Proposed System	Guardian Lecturer A	Guardian Lecturer B	Guardian Lecturer C	Guardian Lecturer D	Guardian Lecturer E
Potentially graduate more than 4 years	Student 1	✓	✓	✓	✓	✓	✓
	Student 2	X	X	X	X	X	✓
	Student 3	✓	✓	✓	✓	✓	✓
	Student 4	✓	✓	✓	✓	✓	✓
Potentially takes more than 7 years to graduate, due to need to retake courses	Student 5	✓	✓	✓	✓	✓	✓
	Student 6	✓	✓	✓	X	X	✓
	Student 7	X	✓	✓	✓	✓	X
	Student 8	✓	✓	✓	✓	✓	✓
	Student 9	✓	✓	✓	✓	✓	✓
	Student 10	✓	✓	✓	✓	X	X
	Student 11	✓	✓	✓	✓	✓	✓
Need to retake course	Student 12	✓	✓	✓	✓	✓	✓
	Student 13	X	X	X	✓	✓	X
	Student 14	✓	✓	✓	✓	✓	✓
Target graduate need to update, due to progress GPS on each term	Student 15	✓	✓	✓	✓	✓	✓
	Student 16	X	✓	✓	✓	✓	✓
	Student 17	X	X	X	✓	X	X
	Student 18	✓	✓	✓	✓	✓	✓
Acceptance level			**88.89%**	**88.89%**	**72.23%**	**72.23%**	**83.34%**
Acceptance value					**81,2%**		

A. Validating Backward Chaining Generated Rules

A system that uses inference rules is considered successful when it operates at the same level of human experts, which in this case are the academic advisers. Therefore, the system is not valid until it indicates that the solutions suggested are consistently in line with those provided by academic advisers. Table 3 shows the comparation result of the proposed model. The recommendations made by the system reached 94.45% conformity level. This value is above the average value of the recommended results from human experts which is in the range of 81.2%. This shows that the recommender system is reliable.

B. Model Implementation

The proposed system is developed in the form of a web-based application using the PHP, CSS, HTML, and JavaScript programming languages to design applications, and the SQL language to design databases. The application has four main features, as shown in Table 2. The transcript updates in CSV format must be included in the study results. Because the data and information handled include sensitive data, MD5 encryption was used as a data security technique. Fig. 2 shows the progress report page. Within this functionality, there is a calculation of the GPA, GPS and the remaining study period. The information visualization is displayed in the form of a progress bar, containing information about the credits taken, those need to be taken, and those retaken. It also has a function to calculate GPA and GPS, which will be used as a factor in the study planning recommendation. The maximum percentage on this bar chart is 99.99% because there are three comparator components. There is information as text concerning the total credits quota for the next semester. The system will display the study period, which maximum limit of four years, and once it exceeds four years, it will automatically change in seven years. There is also information about ‘graduation predicate’, which informs all the credits need to be taken and the absence of E grades.

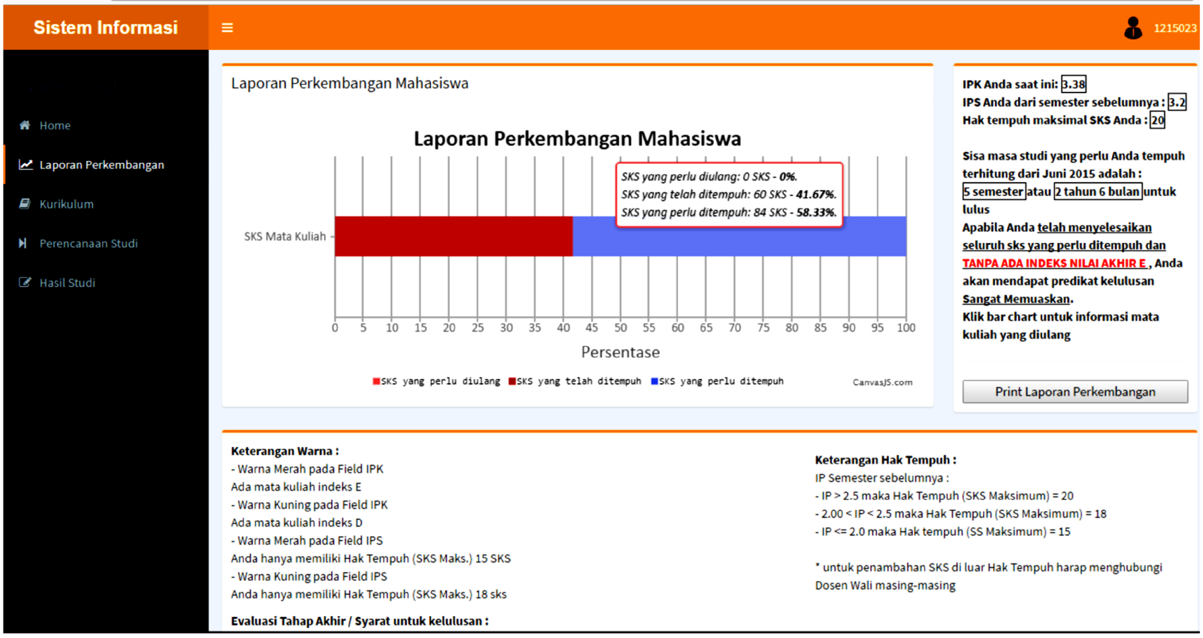


Fig. 2. Input Transcript and Progress Report Pages

Fig. 3 shows the functionality with three tabs: a tab for planning, a tab for compulsory courses to be taken, a tab displaying courses to retake, and elective courses opened next semester. The right-hand panel shows the GPA, the GPS, and the study period. There is a button to calculate the gap between the current GPS and the target GPA, resulting from the output courses and the total credits necessary to obtain a degree. The box at the bottom contains textual information regarding the data displayed on this page. There are also recommendations for priority courses that must be included in even and odd semesters. The page for tracking the realization of the study plan is shown in Fig. 4. This page provides information in the form of pie charts and trend charts, so the adviser can find struggling students and their factors. With the data-access security function, each student has only the right to access his or her respective pages, while the tutor counselor receives a progress report for all students under his or her responsibility.

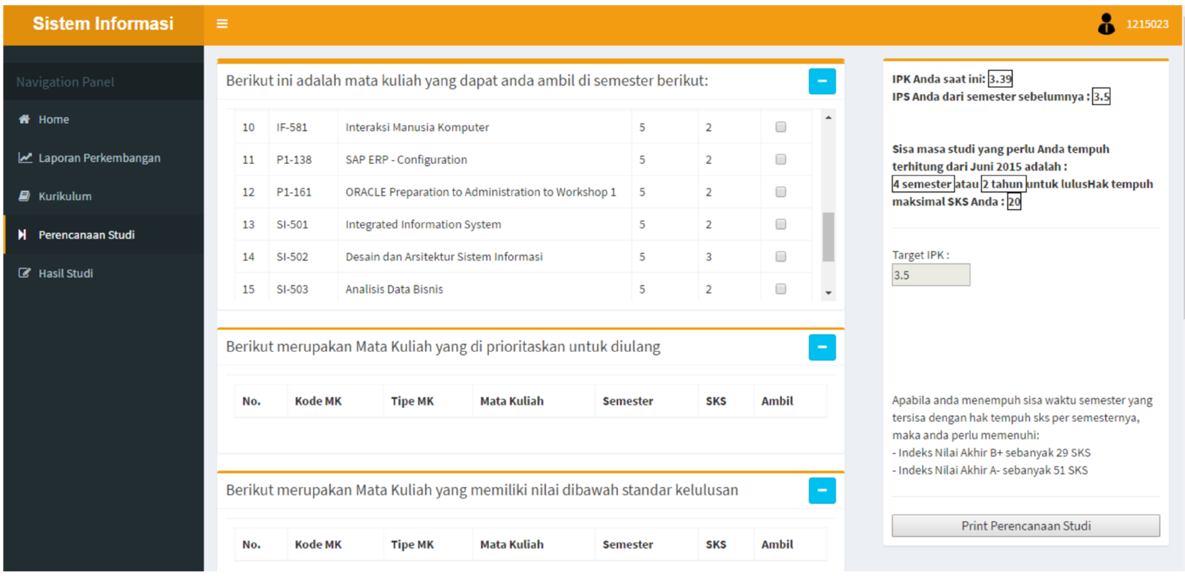


Fig. 3 Study Planning Page

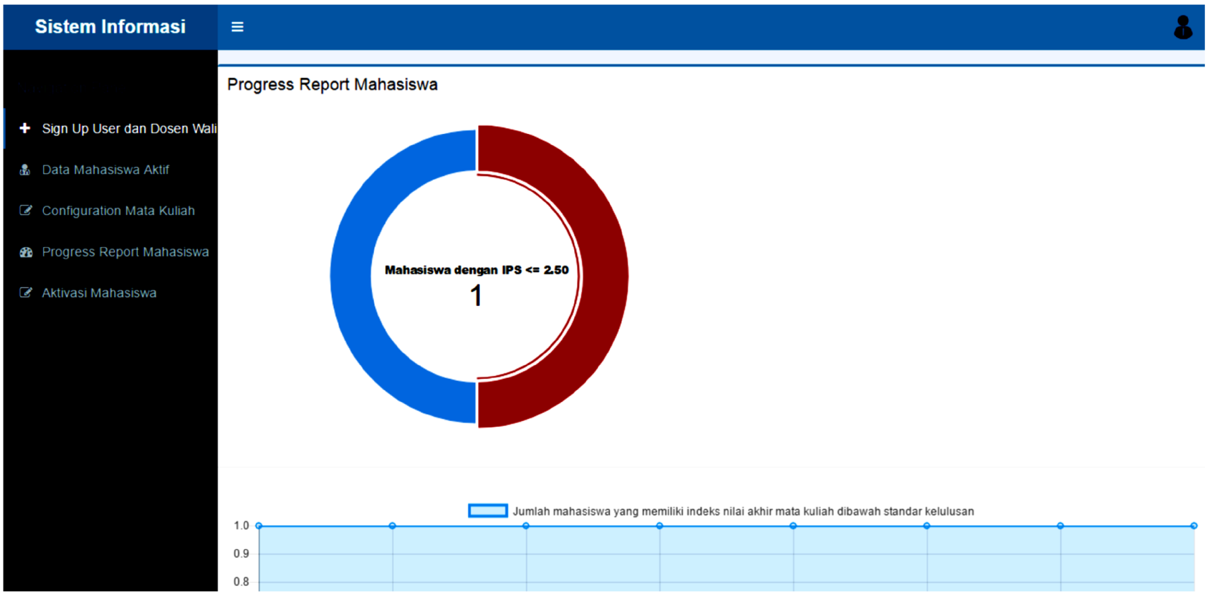


Fig. 4 Progress Monitoring Page

C. Evaluation

From the test results on 15 pages with four main features, it was found that the system can provide output according to the goal-driven rules by updating data on graduation targets and academic performance. The system will also provide notifications for input errors so that users can repeat the step using the appropriate input fields and data formats according to the feature description and data type. The information displayed on the system is visualized according to its data and information type; for example, a pie chart is used to describe the proportion of GPS students.

In this study, the variables evaluated from the TAM model are perceived usefulness and ease of use, because system use is commonly assessed based on these two variables [19]. The TAM-based evaluation was adopted in the form of a questionnaire. This is to assess aspects that affect user experience and intention to use. The detailed variables and indicators measured based on the TAM model are shown in Table 4 [20].

TABLE 4
TAM ADAPTATION FOR SYSTEM EVALUATION INDICATORS

TAM Variables	**Questioner Indicators**	**Correlated of The System Main Features**		
		Study Planning	Simulation	Progress
Ease of Use	Convenience of pages colors and display	✓	✓	✓
	Clarity of information on the navigation panel	✓	✓	
	Clarity of KPI information visualization	✓		✓
	Clarity of information on courses according to the curriculum and sub-majors selected	✓	✓	✓
Perceived usefulness	Understanding and using the system features is easy	✓	✓	✓
	The system can provide progress report of academic KPI	✓		✓
	GPA prediction feature can help academic planning	✓	✓	
	The calculation and projecting GPA, GPS and remaining study period can help academic planning	✓	✓	
	The input and update on academic transcript is easy to use	✓		
	The feature of courses retaken reminder helpful	✓		
	Study proposed system motivate user to achieve academic success	✓	✓	✓

The evaluation aspects are grouped into two groups based on TAM: ease of use and perceived usefulness. Table 3 shows that the two TAM variables were adapted into 11 indicators associated with the system characteristics. It should be noted that the information visualization feature is implied in the other three features. Evaluation indicators were used in a question format on a Likert scale. The results showed that the average total score was 85% for ease of use, and the evaluation of the functionality requirements obtained an average score of 91.2%. It can be concluded that the existing system will assist the academic planning, complete with adjustments to the curriculum and syllabus. Therefore, this system can be adopted for other bachelor programs and majors. The proposed referral system could benefit the educational institution as it provides tools to monitor student participation.

IV. DISCUSSION

Recommender systems have been applied in many fields. In academia, research on this topic remains relevant because many problems are to be solved. Compared to other studies [6] [9] [14] [15], this proposed system's novelty lies in its usefulness and the hybrid approach. Based on the research design, modeling, implementation, and assessment, the proposed recommendation system can help students improve their study plans and comply with the national graduate standard and the ITHB information system study program procedure. The modeled system uses backward chaining, which means that the step rule aims to look for the necessary preconditions for the desired objectives. The backward chaining algorithm performs a set of queries with the graduation target as an objective. The next six steps are taken based on the known rules and the triggering of study planning variables that lead to this target.

The proposed system also provides information and simulations that show students' susceptibility analysis. This process is expected to optimize the time needed for each supervision process. Therefore, the proposed system will help students provide a learning path and a study plan to graduate on time with satisfactory overall results. However, because this system is modeled using the backward chaining model by following expert rules, it needs to be compared with other expert systems. Even though the evaluation results show a conformity level that is far above the average individual level, it is still necessary to carry out an in-depth analysis of the subjective factors that influence the recommendation.

V. CONCLUSIONS

This study proposes a recommender system with a hybrid approach, with a combination of intrusive advising and developmental advising models, with system algorithms that follow the reasoning of the guardian adviser. The function of this recommender system is to provide information and visualization of academic KPIs and historical data. In the modeling, the backward chaining algorithm was applied the advisory process is goal-driven. In addition, the algorithm in the proposed system is flexible and adaptive to facilitate curriculum changes. This quality is important so that the rules-based algorithm can adapt to the constraints in the ITHB information systems study program. The dashboard page on the student side is intended for student self-progress monitoring, so students can apply the development relationship advising model, where they have a bigger responsibility in determining their academic plans. On the adviser side, the dashboard is crucial as a support tool to provide information on their student performance. From the results of functional testing of the system using Blackbox testing and TAM, the perceived usefulness and ease of use indicators variables are quite high.

The next development of this system is to test its accuracy by observing users for at least four years, from the first semester to graduation. The system's features can also be enriched by integrating it into sub-major decision support system modules so it can give a recommendation of electives by student interests and academic performance.

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