

Research Article

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A student-based central exam scheduling model using A* algorithm

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Abstract: In this study, a student-based placement model using the A* algorithm is proposed and applied to solve the problem of placing the courses in exam sessions. The application area of the model is midterm and final exams, conducted by the Open Education Faculty. The reason for choosing open education exams for the practice is that the exams are applied across the country and more than 100,000 students participate. The main problem is to obtain a suitable distribution that can satisfy many constraints simultaneously. In the current system, the lessons in the sessions were placed once using the curriculum knowledge. This placement plan is applied in all exams. When the placement is done according to the curriculum information, the courses in the sessions cannot be placed effectively and efficiently due to a large number of common courses and the large number of students taking the exam. This makes the booklets more expensive and the organization more prone to errors. Both the opening of new programs and the increase in the number of students regularly lead to the necessity of placing the classes in sessions dynamically each semester. In addition, to prevent conflicts with the calendars of other central exams, it is necessary to conduct all exams in three sessions. A better solution was obtained by using a different model than the currently used model in the study. With this solution, distribution of the courses of successful students with few courses to all sessions is provided, and difficult courses of unsuccessful students who have a large number of courses were gathered in the same session. This study can support future studies on two issues: the first issue is

the approach of using the course that will be taken by most students instead of the courses taught in most departments in the selection of the course to be placed in the booklet. The second issue is to try to find the most suitable solution by performing performance tests on many algorithms whose performance has been determined by many academic studies.

Keywords: search algorithms, A* algorithm, scheduling problems, exam scheduling, student-based placement

1 Introduction

Scheduling is a tool aimed at optimizing performance criteria by associating activities with limited resources [1]. When scheduling, jobs are first divided into workpieces. Then, it is determined that each workpiece will be made by which steps and by which sequence. The organization of the exams is generally regarded as a scheduling problem. However, there are many different applications in terms of conditions and restrictors. The existence of different goals and priorities in each academic institution caused different examination scheduling models [2]. When the literature on exam scheduling problems is examined, it can be seen that the vast majority of the studies related to the exam scheduling are related to the timing [3–6]. Studies differ in exam types, goals, variables, and constraints. There are many different approaches to the methods used in the solution of the problem. Mathematical programming models are preferred for problems with low complexity. As the number of variables and constraints increases, it becomes harder to find solutions with mathematical models, and metaintuitive methods are tried. New intuitive models can be used for problems that are more complex. In Table 1, the approaches and models used in exam scheduling are summarized.

Algorithmic complexes and excessive computation time complicate the solution of some multiprocessing problems. In recent years, instead of blind search and hard optimization techniques, especially soft computing, evolutionary algorithms and genetic algorithms have

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Table 1: The approaches and models used in exam scheduling (Altunay and Eren [20])

Approaches	Models
Operation research	Integer/linear programming Graph coloring Network models Multicriteria/multipurpose modeling
Meta intuitive (single solution/ population-based) approaches	Tabu search Simulated annealing Variable neighborhood search Local search Genetic algorithms Ant colony optimization Particle swarm optimization Memetic algorithm Harmony search algorithm
New approaches	Hybrid algorithms Fuzzy methods Clustering algorithms Decision support systems/ expert systems Artificial neural networks Multiple agent systems

come to the fore [7]. Genetic algorithms are used frequently in hybrid solutions along with other soft calculation methods (neural networks, expert systems, fuzzy logic, etc.) [8–11].

A genetic algorithm is used to ensure that lessons with high difficulty are assigned to different periods as far as possible [12,13]. Target Programming and Intuitive Method were used to spread the exams throughout the exam period and to minimize the number of students having repetitive exams on the same day [14,15]. Bergman used the Intuitive Method to minimize the number of students taking the exam in the same session and on the same day [16]. Muklason and Kadry used Goal Programming to ensure that the exam schedule was balanced for each student, to minimize the number of classrooms for each exam, and to ensure that exams were assigned to appropriate time intervals [17,18]. Target Programming and Intuitive Method have been used to minimize flexible constraint violations and ensure fair time distribution per student [19]. Ceylan used the Memetic Algorithm to ensure that exams were assigned to the appropriate timeframe according to their difficulty levels [1].

The constraints used in scheduling problems developed for the examination organization are divided into two groups: hard constraints and soft constraints. Hard

(compulsory) constraints express the conditions that must be met while obtaining a solution. The general purpose of hard constraints is to prevent possible conflicts that may occur. Some examples of hard constraints are as follows [20–22]:

- Exam assignments for all courses in the program must be completed.
- The number of exams to be taken in one session must be determined for all students.
- The capacity of the classrooms to which the exams are assigned should be equal to or greater than the number of students who will take the exam.
- For one lesson, exams should not be held in more than one session at different times.
- There should not be more than one exam in a classroom at the same time.

Soft constraints are conditions that are desired to be met even if they do not contain any obligation. The use of soft constraints is to increase the quality of the exam schedules as much as possible. These constraints belonging to the model are generally included in the objective function expression with priority coefficients and become operational. Some examples of hard constraints are as follows [7,23]:

- Prevention of assigning only one exam in one session for all students.
- Assignment of exams pertaining to relatively difficult lessons to different sessions and ensuring that all students take the exam in the same buildings as possible in all.

2 Schedule of central exams

When defining the exam-scheduling problem, it is important to know whether the exam will be held in a particular school or whether it will be a central exam in more than one school or province. There are important differences between central and decentralized exam organizations.

In the decentralized examination, exam sessions spread over a wider time. There is no flexibility in this matter in the central exams. Exam duration and the number of sessions are determined in advance. Since central exams are usually held on weekends, they should be held in a maximum of four sessions.

In decentralized exams, a separate session is planned for each course. Since there is more than one course in one session in central exams, there is no flexibility in determining different exam periods for each course. In these

exams, the student distributes the total time to the lessons according to his preference.

In decentralized exams, courses are placed in the exam calendar, while in central exams, the courses are distributed to the sessions. In Table 2, the differences between central exams and the organization of decentralized exams are summarized.

3 Problem of distribution of courses to sessions and A* algorithm

For a global solution (minimum or maximum solution), linear or nonlinear programming is used depending on the type of problem. Linear programming is to obtain a clear result using a function within the given constraints. Nonlinear programming is used in cases where linear programming cannot find a global solution or takes a lot of time. However, nonlinear programming often does not guarantee the best solution, and the need to set parameters correctly increases complexity.

Search algorithms for the optimal path problem are used to find a path from a particular start node to the target node [24–26]. All possible nodes to reach the destination node from the start node are called search fields. The search algorithm scans the search field and tries to find the path that leads to the destination node.

Structurally, it is possible to aggregate search algorithms into two groups: uninformed search and informed search. In uninformed search, the search algorithm does not contain any problem-specific facilities. These algorithms use primitive methods that work the same way in every situation. Informed search means that the algorithm contains some features of the problem and therefore changes based on problems. Informed search methods

are relatively more efficient than uninformed search algorithms.

Some informed search algorithms try to reduce the time spent on searching using intuitive functions. A heuristic function has been developed to find a solution closer to the best possible answer in less time. In search algorithms, heuristic functions are used to estimate paths leading to the target node at the lowest cost [27,28]. In this way, only the selected part of the field is searched, not the whole search field. This method significantly reduces search time. Best First Search (BFS) is an example of knowledgeable search algorithms. Greedy search algorithm and A* algorithm are among the BFS algorithms.

A* is a real-time BFS algorithm developed by the Stanford Research Institute in 1968. It was created by combining the Dijkstra algorithm with the Open Eye Search algorithm. In the Dijkstra algorithm, when deciding on the next node, the node with the most appropriate real cost function is visited. In the Greedy Search algorithm, the next node is decided by considering the intuitive cost. In the A* algorithm, among the possible nodes, the node with the smallest sum of intuitive function value and actual cost value is selected. The balance between the speed and accuracy of the A* Algorithm depends on intuition.

$$f(x) = g(x) + h(x),$$

where $g(x)$ is the actual cost from the start node to the current node. $H(x)$ is the estimated cost of the path from the current node x to the destination node.

It is estimated how far the target node is from the current x node. $h(x)$ must be an acceptable intuitive prediction. An intuitive function is said to be acceptable if the estimated cost of the route does not exceed the lowest route cost. Since $h(x)$ is part of $f(x)$, $h(x)$ is used for the lowest path cost. When $h(x)$ is acceptable, it is guaranteed that the A* algorithm will give the shortest path, if any. Therefore, $h(x)$ should not estimate the cost high.

Table 2: Differences between central exams and the organization of decentralized exams

	Decentralized exams	Central exams
Number and time of sessions	The exam period has spread over a wide time. Sessions are placed at appropriate times in the exam schedule	Exam time and the number of sessions are determined in advance. Since exams are usually held on weekends, a maximum of four sessions can be scheduled
Distribution of lessons to sessions	You can take more than one course in a session	Students can take exams in more than one course in a session
Determination of exam periods	Different exam duration can be determined for each course	The student distributes the total time to the lessons according to his wishes

Parental node and node status (“not visited,” “open,” or “closed”) are recorded for each node. The status of the node visited is marked as “open” and placed in the open list. When all neighboring nodes of an open node are visited, its status is changed to “closed.” This node is removed from the open list and other options are explored by returning to the parent node.

There are not many studies in the literature about using the A* algorithm to distribute the lessons to sessions in central exams [29]. Aygün and Akçay [30] analyzed the performance of the A* algorithm with a different number of processor cores to go from A to B between provinces within a certain distance. The study by Inam focused on the parallel programming (with Cuda architecture) approach to solve the speed problem of the A* algorithm [32]. Bulut and İnce were able to reduce the calculation time by applying an intuitive and greedy approach to the integer programming method by applying it to the “backpack” problem [7].

4 Central exam planning system design

4.1 Institutions organizing

Central exams in Turkey institutions that practice central exams in Turkey are divided into three groups:

1. Student Selection and Placement Center (ÖSYM)¹: The most common exam that it organizes is a three-session exam, which involves more than 1.5 million people and aims to place students in universities. Apart from this exam, ÖSYM organizes more than 50 exam organizations on behalf of different institutions.
2. Ministry of National Education (MEB)²: The most important examination that it carries out is the final exams for Open Education High Schools. These exams are held in two-day sessions and three times a year. Apart from these exams, it also organizes e-exams for an exam that must be taken to obtain a driver's license.
3. Open education faculties³: Universities try to use distance education models in addition to formal education.

¹ The institution responsible for the organization of central exams in Turkey.

² The institution responsible for the execution of educational activities in Turkey.

³ Faculties were established within the university and authorized to carry out open education activities in Turkey.

Distance education centers offer education in many universities, but the actual widespread central examination is carried out in open education faculties. Open education faculties are available in only three universities in Turkey. These are Anadolu University Open Education Faculty (AOF), Atatürk University Open Education Faculty (ATA-AOF), and Istanbul University Open and Distance Education Faculty (AUZEF).

4.2 ATA-AOF center exams

ATA-AOF conducts exams in which a total of 150,000–200,000 students participate in 83 city centers. While organizing these exams, in addition to the processes directly related to the exam, many auxiliary activities should be carried out simultaneously. The main activities in the examination organization are as follows:

- Determination of exam sessions and distribution of courses to sessions;
- Editing booklets;
- Organization of exam buildings and halls; and
- Organization of examiners.

Auxiliary activities carried out in the examination center, apart from the main activities, are as follows: preparation of questions, preparation of course materials, the printing of question booklets and examination documents, transportation, evaluation of answer forms, evaluation of objections, etc.

The activities of an examination organization for ATA-AOF are shown in Figure 1. As it is seen in the figure, the distribution of lessons to the sessions and question preparation processes are two processes that should be carried out primarily within the examination organization. The process of preparing and controlling questions may take longer, as it takes longer, but to proceed to the Print phase, it is necessary to determine how the lessons will be distributed to the sessions, how the students will be distributed to the halls, and the content of the question booklets.

As of 2020, there are 190,113 active students in 29 programs at ATA-AOF. Programs with the most students are as follows: child development associate degree (279,292), occupational health and safety associate degree (193,004), and justice associate degree (107,128). Programs with the least number of students are as follows: call center services associate degree (3,083), occupational health and safety license completion (2,092), and computer programming associate degree (186).

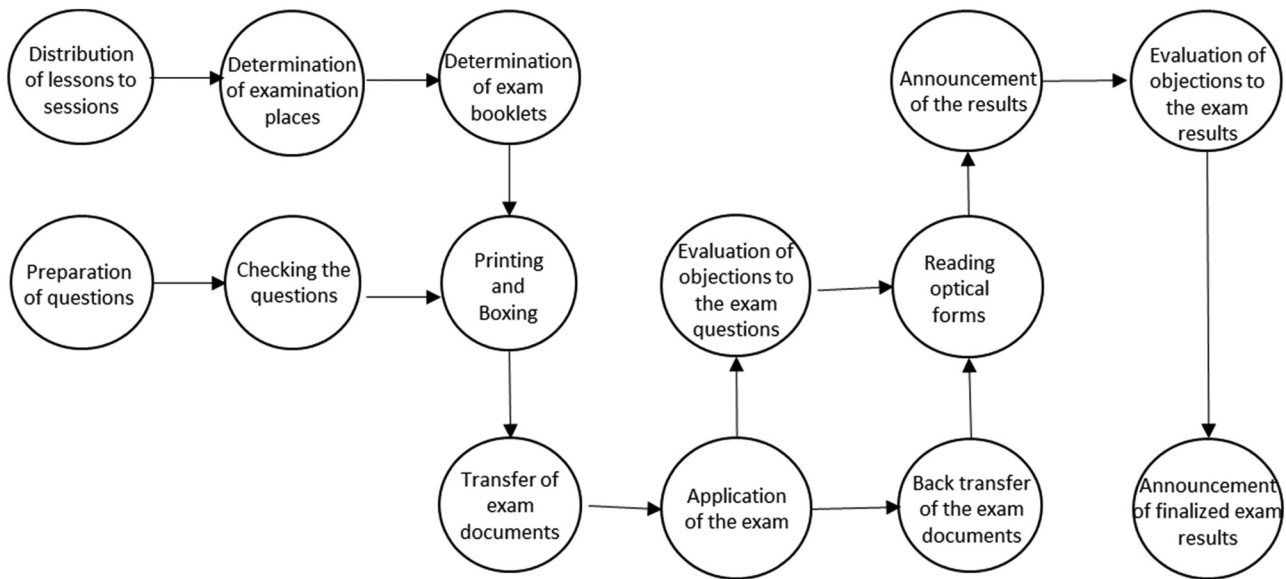


Figure 1: ATA-AOF exam organization.

The total number of courses taught in the programs is 421. Only 85 of these courses are in a single program. Other courses are included in two or more sections. “Turkish Language I” and “Ataturk’s Principles and Revolution History I” courses are included in 26 different programs. The number of courses in more than one program is listed in Table 3.

The majority of students (80%) take exams in more than five lessons. This means that they have to take the exam in at least two sessions. The distribution of the number of courses students will take for the exam is shown in Table 4.

Considering the number of students, the number of departments, the number of courses taken by the student,

Table 4: Distribution of the number of courses

The number of courses the students take the exam	The number of students taking the exam	Percentage
1	6,155	3
2	5,521	3
3	5,272	3
4	5,535	3
5	15,839	8
6	42,656	22
7	50,043	26
8	15,028	8
9	12,847	7
10	31,217	16

Table 3: Number of courses in more than one program

Number of programs with the course	Number of courses
26	2
25	1
24	1
20	1
14	2
13	1
12	1
11	1
9	2
6	3
5	4
4	4
3	7
2	29

the number of common courses, and the number of different departments in which these courses are given, the problem of placing the sessions becomes more complex [31]. In the current situation, the curriculum information has been taken into consideration to place the courses in the sessions and the courses have been placed considering the program–course relationship.

5 Defining the problem

The problem of distributing lessons to sessions is currently solved using the ant colony algorithm, and this was done once, about 3 years ago. Increasing the number

of students regularly and opening new programs every year revealed the necessity of doing this dynamically. The need to ensure time and cost-effectiveness and increase student satisfaction and new constraints resulting from these needs have been other motivating factors for improving the process. The objectives of the new method to be applied in terms of these factors are determined as follows:

- Reducing the number of transactions and total processing time;
- Reducing exam implementation costs by using less buildings and classrooms in sessions;
- Lessons are distributed to booklets in an optimal way, saving time in printing and boxing of exam documents and reducing errors; and
- Increasing the total academic success and student satisfaction by ensuring that the demands of the students regarding the exam sessions are met as much as possible.

Exams can be held on weekends and in four sessions (Saturday morning, Saturday afternoon, Sunday morning, and Sunday afternoon). However, to avoid conflicts due to central exams by other organizations, it was decided by the faculty administration to conduct all exams in three sessions. On the other hand, since it was allocated 30 min for each course, it was decided by the faculty management that it would not be appropriate for a student to take the exam in more than five courses in one session.

Most of the courses taught by the faculty are in the curriculum of more than one department. These courses, which are called common lessons, have the same learning outcomes, course content, textbooks, and exam questions for each department. Therefore, exams for these courses should be held in the same session for all departments.

The hard constraints of the problem of determining the courses in the exam sessions are as follows:

- All exams should be held in three sessions, two on Saturday and one on Sunday.
- A student can take the exam in a maximum of five courses in one session.
- Although it is educated in different departments (common course), the examination of one course cannot take place in more than one session.

Students will take the exam in one or more sessions after the lessons of the active students are distributed to the sessions. On the condition that they take five or fewer lessons, some students can fit all

the lessons in one session. Some students with three or more courses are divided into three sessions. Some students' lessons can fit into two sessions.

When the feedback from the students were examined, it was understood that the students whose exams were distributed for 2 days and morning sessions would be high satisfaction. In addition, it was evaluated that the distribution of the courses that the students had difficulty achieving in different sessions would increase student success. Since the high number of optics will increase the costs of staff and other costs, it is also an important goal to reduce the number of students as much as possible, who take the exam in three sessions.

The soft constraints of the problem are as follows:

- As many students as possible take the exam in two sessions;
- Difficult distribution of difficult lessons; and
- The number of optical forms used in the exam is as low as possible.

In accordance with the information given above, the aim function of the model was determined as maximizing the number of students who had the exams in the first and third sessions and no exam in the second session (first group) in the same exam period and also minimizing the total number of optic forms. While minimizing the number of optics, students who will take the exam from more than five lessons have been tried to take the exam in two sessions if possible. In addition, although it is not a mandatory constraint, a solution is aimed to allow difficult lessons to be placed in different sessions on different days.

6 Solution to the problem

While distributing the courses to the sessions, a balanced distribution was aimed for the first (CS) and third (PS) sessions, while it was preferred to place as few courses as possible in the second (CO) session. In this way, in the second session, it is desirable to include lessons that are inconvenient according to the hard restrictions included in the first or third sessions and those that are useful in terms of soft restrictions to be included in the second session. In this context, the first course to be placed in the first session (CS1) will be the one with the highest number of students to take the exam. This method helps to control the distribution of students to the sessions in

terms of the number of students to take the exam in each session, as well as to evaluate the degree of difficulty of the lessons. While determining the first course to be placed in the second session (PS1), the second-highest number of students can be looked at. This method can provide numerical balance but in this case, a balanced distribution in terms of constraints is ignored. Instead, courses with the highest number of joint students with CS1 will be preferred. Likewise, distribution is made by controlling the number of common students with PS1 for CS2 and CS2 for PS2. All courses are distributed using this method. Each time, it is necessary to check whether the selected course is suitable for the limitations of the problem, and if there is a nonconformity, the second-best option should be evaluated. After the first distribution was planned in this way, the A* algorithm was run. The pseudocode code of the A* algorithm is given as follows:

1. Define constraints;
2. Define the nodes;
3. Assign heuristic values to nodes;
4. Define the termination condition;
5. Decide on the starting node;

6. Draw a path to the node with the highest heuristic value;
7. If it does not comply with the defined constraints, go to step 10;
8. Calculate the actual function value of the path;
9. If there are no nodes left to go to, go to step 11;
10. Mark this node as closed and return to step 5; and
11. Report solution.

The reason for using the A* algorithm in this study is the high cost of testing all solutions in the solution space. For this, it is necessary to use heuristic functions that approximate the most appropriate solution as in the A* algorithm. The features that distinguish this algorithm from other heuristics are that it is easy to design and real costs can also be included in the calculation to a certain extent. Algorithm codes used in the study were written in TSQL language using MsSQL. Queries using index-defined tables are optimized by writing as stored procedures. When it is run on a machine with an Intel i5 processor and 8 GB RAM without sharing, the results of the study could be obtained within 110 min.

Table 5: Statistics for students and sessions

	Number of students	Percentage
Students who took the exam in the first session	177,114	93
Students who took the exam in the second session	128,502	68
Students who took the exam in the third session	177,017	93
Students who took the exam only in the first session	3,375	2
Students who took the exam only in the second session	2,879	2
Students who took the exam only in the third session	2,609	1
Students who took the exam in first and third sessions	55,627	29
Students who took the exam in the first and second sessions	6,842	4
Students who took the exam in the second and third sessions	7,511	4
Students who take the exam in one session	8,863	5
Students who take the exam in two sessions	69,980	37
Students who take the exam in three sessions	111,270	59

Table 6: Number of courses that students take the exam in sessions

	Number of students		
	First session	Second session	Third session
Students without any exam	12,999	61,611	13,096
Students who take the exam from a course	31,920	35,202	38,297
Students taking the exam in two courses	49,987	26,758	31,800
Students who take the exam in three courses	49,197	17,536	61,485
Students who take the exam in four courses	40,953	40,822	39,041
Students who take the exam in five courses	5,057	8,184	6,394

Table 7: The balanced distribution of the lessons to the sessions

	Number of students	Percentage
Students whose exams are distributed balanced to first and third sessions	52,159	27
Students whose exams are distributed balanced to first and second sessions	6,882	4
Students whose exams are distributed balanced to second and third sessions	6,791	4
Students whose exams are balanced to all sessions	15,656	8

Table 8: The number of lessons of the programs in the sessions

Number of lessons	First session	Second session	Third session	Number of programs
12	4	3	5	1
12	5	2	5	1
12	5	3	4	1
13	5	3	5	2
13	6	3	4	1
14	5	3	6	1
14	5	4	5	15
14	5	5	4	1
15	5	5	5	4
23	9	6	8	1

7 Results

Using the developed approach and algorithm, all the courses could be assigned to the sessions within the determined constraints. During the exam period, 80% of students took the exam from six or more courses and 9% took the exam from three or less courses, 41% of all students took the exam in one or two sessions. The number of students who took the exam in the second session was minimized compared to the other sessions (Table 5), and the number of students taking exams from five lessons was reduced in one session (Table 6). In addition, it was ensured that the courses of the students who took the exam in two sessions were distributed

Table 9: The number of lessons of the programs in the sessions

	First session		Second session		Third session	
	Num.	Percentage	Num.	Percentage	Num.	Percentage
Emergency and disaster management	16,583	36	12,152	26	17,866	38
Emergency aid and disaster management (U)	12,680	44	4,679	16	11,424	40
Justice	37,232	35	30,526	28	39,370	37
Banking and insurance	6,755	43	3,957	25	4,909	31
Knowledge management	4,882	39	3,014	24	4,688	37
Computer programming	80	43	40	22	66	35
Office management and executive assistance	6,156	38	5,094	31	5,017	31
Call center services	1,076	35	671	22	1,336	43
Child development	91,999	33	90,304	32	96,989	35
Foreign trade	4,224	38	2,967	27	3,892	35
Real estate and property management	5,921	39	3,503	23	5,723	38
Photography and videography	3,109	44	1,586	23	2,333	33
Public relations and publicity (U)	15,613	32	14,817	31	18,124	37
Public relations and publicity	6,766	38	5,078	29	5,880	33
Theology	23,805	37	16,778	26	24,525	38
Occupational health and safety	833	40	524	25	735	35
Occupational health and safety (U)	64,736	34	55,790	29	72,478	38
Business (U)	11,109	41	6,677	24	9,636	35
Business administration	7,305	44	3,639	22	5,555	34
Public administration (U)	2,844	43	1,494	23	2,220	34
Laboratory and veterinary health	11,854	44	3,572	13	11,270	42
Logistics	4,720	37	3,045	24	5,032	39
Private security and protection	6,219	41	3,171	21	5,946	39
Radio and television programming	2,429	44	1,241	22	1,886	34
Advertising (U)	6,418	43	4,493	30	4,004	27
Advertising	2,055	40	1,462	29	1,565	31
Management of health institutions	6,107	39	3,859	25	5,722	36
Health management (U)	6,612	40	3,088	19	6,640	41
Health management (U)	5,260	32	4,907	30	6,234	38

U: undergraduate.

evenly to the sessions (Table 7). In total, the proportion of students whose courses can be distributed in a balanced way was determined as 43%. Lessons could be distributed to sessions in 20 programs (Tables 8 and 9). As a result, the number of documents to be used for all sessions has been reduced by approximately 15,000 (total number of optics: 482,633).

8 Conclusion

The developed model ensured that all courses were distributed to sessions in accordance with the purpose function and constraints. In addition, situations that cause dissatisfaction with the exam organization were prevented. These situations are as follows:

- The distribution of the courses of successful students with few courses to all sessions and
- Difficult courses of unsuccessful students with a large number of courses are gathered in the same session.

When the statistics are analyzed, it is seen that a large part of the students has more than five lessons. In the proposed model, since the difficult lessons were taken by many students, they were placed in sessions on different days according to the number of common students. It is considered that this situation will increase the academic success of students. A total of 95% of students took the exam in two or three sessions. A total of 89% of the students whose exams are distributed in two sessions were taken on different days (sessions 1 and 3). While the percentage of students who took the exam in the second session was 68, the percentage of students who took the exam in three sessions was 59. Students who took the exam in five lessons in one session constituted 10% of all students. The percentage of students whose lessons can be distributed balanced to the sessions was 43. The students whose lessons are distributed equally in the first and third sessions are 27%. When analyzed by the department, it is seen that 77% of the courses are distributed to the sessions in a balanced way. It is seen that the number of students taking the exam in the second session is less than in the other sessions in all programs except two programs. On the other hand, since the number of optics can be reduced by approximately 15,000, the number of buildings, halls, and supervisors used in the exam has been reduced as well.

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