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GAME-DAY SCHEDULING PROBLEM FOR SPORT EVENTS

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GAME-DAY SCHEDULING PROBLEM FOR SPORT EVENTS

Abstract

In recent years, sport organizations are not only entertaining events attracting millions of audience worldwide, but also have they become growing industry in which billions of dollars are circulating. Significant amount of investments in sport events are controlled by associations such as FIFA, UEFA, and National Basketball Association (NBA), and they organize world-famous sport events such as FIFA World Cup, UEFA Champions League, or NBA men's professional basketball league. These events attract great amount of worldwide audiences through conventional and social media and can generate billions of dollars as revenue. A key aspect of these sport events is successful planning and scheduling of their games, which ensures each participant of the competition is equally treated, and no participant gain advantage over its competitors through the course of the event. The preparation of well-organized sport event schedules may sometimes lead to complicated modeling problems.

In this research, we first define such a sport event scheduling problem in which the days of the games has to be decided for a given fixture of a sport organization without violating some given restrictions that aim to preserve the equity among competitors. We then develop a mixed integer programming model for the defined problem that uses combinatorial optimization techniques. In the final step, we test our model with the data set of 2013-2014 season of the Turkish Super League (top-tier men's professional football league in Turkey) organized by Turkish Football Federation (TFF) in three different decision environments: *(i)* game-day scheduling of league games all at once by ignoring national cup and international (European cup) fixtures, *(ii)* game-day scheduling of league games all at once by considering predetermined

national cup and international (European cup) fixtures, and *(iii)* deciding the days of league games in real time (i.e. week by week) when national cup and international fixtures become clear after their games have been completed. In all three decision environments, the performance of our model, i.e. how successful our model is in preserving the equity among competitors, has been compared to the performance of the game-day scheduling decisions of Turkish Football Federation. We show that in all decision environments our game-day schedule performs at least 7.8% better than TFF's schedule. This result proves that organizers of the sport events can give much effective and equitable decisions by the help of mathematical modeling techniques as opposed to the current practice, in which the game-day schedule is decided manually.

Keywords: *Sport Event Scheduling; Sport Competitions Models; Mathematical Model Applications; Integer Programming*

To my family and Can Çamlık

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CHAPTER 1 - INTRODUCTION

1.1 Problem Statement

The process of sport scheduling is one of the most common and important part of all sport organizations in the entire world because it affects proper running of both domestics and national competitions. It is the reason why many scientists are interested in sports scheduling, planning, and adaptation of these plans for tournaments and leagues [1]. These types of problems have many different aspects such as the venue where the competition takes place, the time period when the competition occurs, and how long each competitor has rested before the game. In fact, sports scheduling problems cover a wide variety of problems ranging from planning of game venues to the daily (and sometimes even hourly) assignment of tournament games. For example, inequitable assignment of referees or match days may cause problems during the season. The goal of sports scheduling problem in our research is to create a feasible and equitable schedule. However, scheduling is an onerous task, and it includes many subtasks such as creating a feasible competition plan with lots of constraints. For instance, competing teams may have uneven distribution of rest periods before matches through the season. This type of inequalities among competitors have to be considered in detail and addressed properly.

This research is based on game-day scheduling problem for sport events where optimization techniques are used. Match-day (game-day) scheduling problem aims to decide on which day each competing team will have its game in each week of a season. Even though sport event scheduling also involves the determination of the league fixture (i.e. the schedule showing in which order each participant will have its games with its competitors), in most cases it is determined by lot and is not the main focus of this research.

The main objective of game-day scheduling problem is to minimize the inequity for all teams so that match days assignment should be distributed in an equitable manner as much as possible. For instance, if there is a game (match) on a specific match day, the teams who are going to play against each other should have equal resting periods. Unless there is an equal resting period, a penalty should be applied for the team who has less resting period. This kind of penalties are probable for all teams during the competition if there is an inequality in the resting periods of competing teams. The penalties of the problem are used in the objective function of our mathematical model. The objective of our model is to minimize this penalties. Once our model is executed and the game-day scheduling is determined, all matches are played according to the match calendar which is obtained by our research.

As an example, let's assume there is a game (match) in 6^{th} week of season between *teams i* and *j*. Also assume *team i* has played its game on Saturday and t*eam j* has played its game on Monday in the previous week (5^{th} week). Now let's say they are going to play against each other on Friday in 6^{th} week of the season and they will not play any midweek matches between 5^{th} and 6^{th} weeks. As it can be seen in Table 1.1.1, they will not have equal resting period. *Team i* will rest 2 more days before its match compared to t*eam j*. This inequity between the teams should be added to our mathematical model as a penalty of magnitude of 2. We should calculate this type of penalties for all teams in the competition and for all consecutive weeks. Finally, all these penalties are accumulated to obtain the total penalty in the objective function that needs to be minimized.

Table 1.1.1: A Part of Fixture

	Weeks of Season	
Teams	5th Week	6th Week
i	Saturday	Friday
j	Monday	Friday

Many federations who realized the importance of planning schedules are working with specialized professionals for their competitions to organize their schedules. For

example through this method, the Barclays Premier League (i.e. England Premiere League, EPL) can declare the match days two months before the game. [2].

Turkish Super League (TSL) was organized by Turkish Football Federation (TFF). TFF declares the league fixture almost one month before the beginning of season. However, they declare the game-day schedule only one week before the game weekend [3]. This system is causing some problems in short-term planning of teams such as their training schedule, travelling schedule and rest periods between consecutive games. The chairmen of Football clubs and their managers who are affected by this system, are constantly criticizing this current practice. For example, Zeki Önder Özen who was the sportive director of Beşiktaş Football Club in 2014, emphasizes this problem from his perspective as follows:
"In terms of the match schedule, we want to have equal resting period as the competitors have. In total Fenerbahçe rested 6 days more, and Galatasaray and Kasımpaşa rested 4 days more (compared to their competitors) during the first half of the season, but we rested 13 days less than our competitors. I do not understand it. We also want justice in football field." [4].

In a similar manner, in the press conference after a European match, the manager of Galatasaray Football Club, Cesare Prandelli, had criticized that TFF assigned their league match three days after the European match [5]. In recent years, there were many similar objections by other teams due to the intensive traffic of contests which include the European Cups, Turkish National Cup, and the games of the Turkish National Team.

Table 1.1.2 provides information about the relative resting duration of the teams of Turkish Super League in the 2013-2014 season:

Table 1.1.2: Rest Period of Turkish Super League Teams in 2013-2014

		more rest time than other competitors	number of more rest matches than other competitors	number of less rest matches than other competitors	number of equal rest matches than other competitors
1	Akhisar Belediyespor	-6	9	12	13
2	Antalyaspor	-15	12	13	9
3	Beşiktaş	17	18	9	7
4	Bursaspor	-5	14	13	7
5	Çaykur Rizespor	10	10	10	14
6	Elazığspor	-29	9	17	8
7	Eskişehirspor	-23	13	11	10
8	Fenerbahçe	17	12	14	8
9	Galatasaray	-44	13	10	11
10	Gaziantepspor	14	8	14	12
11	Gençlerbirliği	18	10	14	10
12	Karabükspor	6	10	11	13
13	Kasımpaşa	39	16	11	7
14	Kayserispor	5	14	11	9
15	Kayseri Erciyesspor	17	11	11	12
16	Sivasspor	-5	10	14	10
17	Torku Konyaspor	20	11	11	12
18	Trabzonspor	-36	16	10	8

The first column (more rest time than other competitors) shows the accumulated relative rest time of teams during the entire 2013-2014 season in Turkish Super League. The negative numbers indicates that the corresponding team rests less than its competitors during the season, and the positive numbers indicates that the corresponding team rests more than its competitors during the season. However, the most critical issue in Table 1.1.2 is an unequal distribution of the total rest times among teams. As it shown in Table 1.1.2, Kasımpaşa's total relative rest time is +39 days, which is found by summing the relative rest times of Kasımpaşa over all of its games through the season. On the other hand, Galatasaray has relative rest time of -44 days. Thus, the absolute difference between these two teams' total relative rest times has been formed as +83 days, which is a good indicator of huge inequities between competing teams.

For example, the following vector indicates the number of days by which Akhisar Belediyespor has rested more with respect to its competitor for each week of the entire season:

[0,-1, 6, 0, 0, -2, 5, 0, 1, 0, 1, 1, -2, -2, -1, 0, -3, 0, -5, -2, -4, -2, -1,2, 1, 0, -1, 2, 0, 0, 1, 0, 0, 0]

The number of positive numbers in the above vector gives the number of weeks in which Akhisar Belediyespor rested more with respect to its competitors. The number of negative numbers in the vector gives the number of weeks in which Akhisar Belediyespor rested less with respect to its competitors in the corresponding week. The number of 0's in the vector gives the number of weeks in which Akhisar Belediyespor rested same amount of days with respect to its competitors.

The sum of all numbers in the vector above (which is -6) gives the total number of days by which Akhisar Belediyespor has rested more (or less) with respect to its competitors. Similar calculations of resting times are performed for each team and Table 1.1.2 is constructed consequently. The minus sign of -6 means that Akhisar Belediyespor has rested less than its competitors during the season.

To sum up, operation research has the potential to solve problem using methods such as optimization and mathematical modelling. Game-day scheduling problem for sport events provides each team an equitable and fair approach. In other words, for a more fair distribution, the first column should be close to zero for each team by using operation research methods. If the whole matches are played on the same day (for example Sunday) of each week during the season, the first column (more resting time than other competitors) would be zero for all teams. Although theoretically this situation is possible, it will not be a feasible solution in real life. Definitely, there will be differences among the total relative rest time of teams during the application of game-day scheduling. However, the discipline of operation research aims to minimize these differences by using mathematical modelling.

1.2 Research Objective

Professional sports events need an effective plan which is accepted by all stakeholders. To ensure effective planning, one can take advantage of *optimization*. Optimization

may produce a solution which everyone will be satisfied with in the long run. As previously mentioned in Section 1.1, operations research has the potential to solve these problems by using mathematical modeling method and optimization. Also the results of operation research will be more reliable and equal for all teams. Further, Game-day scheduling problem, as a part of sports planning, can provide an equitable schedule for all teams during the season.

A solution produced for the game-day scheduling problem has many advantages such as possible early planning, regular rest time, and equal distribution of game day for all teams. As mentioned previously, there may occur some inequalities in scheduling which must be addressed to be more equitable assignments. The mathematical model which will be defined in chapter 3 is developed for this purpose. The mathematical modeling is essential to solve the game-day scheduling problem which results in less objection by competitors. One of the most important benefits of the game-day scheduling problem is that developing the software by using mathematical model can be applied to determine the fixture without any critic mistakes. In light of this information, travelling plans for the away matches and training schedules of the teams can be organized more efficiently.

In addition; form the financial point of view, sport events are among the most important entertainment industries in the world. Therefore, professional sport events must have schedule which is accepted by all stakeholders. For instance, because of the trend in rating of football matches in Turkey, derbies are usually played on weekend (Saturday or Sunday) and these decisions are substantially forced by the TV network holding the right of broadcasting. As a consequence of this agreement, broadcasters makes better profit out of the games and, in return, offers higher money for the broadcasting rights of the games in future possible auctions.

1.3 Limitations and Assumptions of the Research

This thesis is based on the integer programming approach to the game-day scheduling problem. Although there exists many methodologies for sport scheduling, we focus

our attention on to the integer programming applications. The integer programming approach solves significantly larger problem in less time if problems are formulated efficiently and solved in state-of-the-art optimization software. Moreover, unpredictable conditions such as election day in the country, which may disrupt the usual flow of sport schedules, are ignored in this research. However, many unpredictable conditions can be planned in the schedule. As it will be explained in the forthcoming sections, real time implementation of the mathematical programming approach might prove to be more effective in this unpredictable conditions. In this research, CPLEX Optimization Studio, a commercial optimization software package, is used for modelling the game-day scheduling problem, as well as integrating mathematical programming components [6].

1.4 Outline of the Thesis

This research is arranged as follows: In Chapter 1, we define the game-day scheduling problem. We present general outline of the research, the details of the problem, and critical points of schedule planning for sport events. A review of the available literature relevant to our work is presented in Chapter 2. Then in Chapter 3, we present a formal mathematical definition of the problem by a mathematical programming model. In this chapter, we also present an integer programming approach to find a solution that satisfies all of the constraints. In addition, we explain methodology of game-day scheduling problem for sport events and its mathematical formulation. Chapter 4 presents the data which we used on our models, the experiments conducted with this date, and the results of these experiments. Chapter 5 discusses implementation of the mathematical model for the game-day scheduling problem in real time. In this chapter, we described the stages of the application in detail. We first present our additional data used for the real-time implementation and then provide the experimental results to depict the performance of real-time implementation. Finally in Chapter 6, the thesis closes with a brief summary, conclusions, and future research directions.

CHAPTER 2 - BACKGROUND

Operation Research (OR) was criticized during the World War II. A group of British scientists interested for the best beneficiation of war material. After the war, the advantages of ideas which were useful for military operations, were added for development of productivity for civilian sector [7].

Our study is based upon the utilization of OR methodology in sport scheduling problems. In recent years, there has been a lot of works about the importance of the unity of the sport competitions. The scheduling of sports competitions has recently been receiving a great deal of attention in the operational research literature [8]. Although there exists several other calculation methods in the literature about combinatorial problems, we choose integer programming to solve our problems. For example, Nemhauser and Trick [9] explain that scheduling was organized by manually in Atlantic Coast Conference (ACC) which is a group of nine universities in the southeastern United States that compete against each other in sports. An approach is developed for scheduling problems by using an integer programming. Their schedule was accepted by the ACC for season 1997–1998. Martin Henz [10] shows that finite-domain constraint programming can provide a software, is shown in the round robin tournaments.

The KNVB (Royal Dutch Football Association) is responsible for the equitable timetables for the professional football leagues in Netherlands. Because of the competitions' requirements, the KNVB ask for the Faculty of Applied Mathematics of the University of Twente to support them about organizing timetables [11].

Because of importance of scheduling the league games, Ken McAloon, Carol Tretkoff, and Gerhard Wetzel [12] were interested in timetabling problem of the scheduling process which defines the “round robin” schedule and “period” as we interested for our research.

In their research, Russell and Urban [13], and Van Hentenryck [14] are interested in constraint programming, which suggests a suitable mean of solving highly constrained, combinatorial problems such as scheduling and timetabling. Calculation methods are shown in Russell and Urban research. An integer programming model was used to solve our sport-scheduling problem and this approach has determined the best optimal solution.

The experiments of Lim et al. [15], Burke et al. [16], De Werra [17], De Werra et al. [18], Wright [19], and Costa [20] show that the approaches embraced on a formulation for the scheduling problem as a problem of operation research techniques. Experimental results show that these approaches perform as existing methods which are about for solving scheduling problems.

The sport scheduling of sport events is one of the most common and important part of all sport organizations in the world. It is the reason why many scientists such as Bao [21], Schaerf [22], Lee [23], Wright [24], Widmer [25], Henza [26], Rasmussen [27], Burke [28], Ernst [29], Bartsch [30], Wright [31], and Croce [32] are interested in scheduling and planning, and adaptation of these plans for tournaments and leagues such as EPL, La Liga, NBA, NHL etc.

The scheduling of sport competitions has becoming very important for operational research literature. Over the years, through a series of researchers’ works, this type of problem has become easier to solve. Success in ensuring these schedules has depended up on a few important conditions such as planning of team training schedule, travel schedule and rest time of teams.

CHAPTER 3 - GAME-DAY SCHEDULING PROBLEM (GDSP)

3.1 Methodology

The aim of the integer programming approach to game-day scheduling problem (GDSP) is to optimize match days for competitions. There should be an objective function to optimize a specific objective and a set of constraints to identify a feasible schedule. The mathematical model and its optimization software script for this problem are constructed to minimize the number of inequities in the league schedule.

We developed a mathematical model for **G**ame-**D**ay **S**cheduling **P**roblem (GDSP). We provided an integer programing formulation to solve the GDSP which can be described as follows.

The teams in a competition are defined as $i \in I = \{1, 2,.., n\}$. Each competition will be played in a specific day $d \in D = \{1, 2,\ldots, d_f\}$) where d_f is the last day that a match can be assigned to in a week during the period of season. Week through the season are defined as $k \in K = \{1,2,..,2n\text{-}2\}$. There are also some specific teams which are called the *TopTeams*. In terms of their history, success and trophies, several teams are defined as the *TopTeams* in the model. The matches between *TopTeams* are known as derbies and very famous in their domestic competitions such as: Galatasaray - Fenerbahçe, Real Madrid - Barcelona (El Clasico), Boca Juniors - River Plate (Superclasico), Liverpool - Manchester United, Atletico Madrid - Real Madrid.

Let x_{idk} represent the details of teams which indicates specific data for a specific team, a specific match day, and a specific match week. The structure is defined as follows:

$$x_{idk} = \begin{cases} 1 & \text{if team } i \text{ has its game on } d^{th} \text{ day of week } k; \\ 0 & \text{otherwise} \end{cases} \quad (11)$$

In addition, a set of decision variable are identified as seen in equation (12) in the model. The *F* table is constructed to analyze clearly the game days during the competition and that table is shown in Appendix C. Game days of the teams in the *F* table can be obtained by using x_{idk}. Mathematically, the game day of team *i* in week *k* can be defined by using expression: $* x_{idk}$, which gives the match day as F_{ik} in the *F* Table. That mathematical structure of our decision variable will be used in lots of critical points in the GDSP model. For instance, if we define the match days from Friday to Monday, all F_{ik}values in the *F* Table will appear as one of 1,2,3,4 values to represent the game-day of the match. For the sake of convenience, F_{ik} decision variable would help to construct the model and to write the model easily.

The decision variable, which is explained above, will have the following relationship:

$$F_{ik} = d * x_{idk} \quad (12)$$

For example; if team *i* has the match on a game day which is assigned to Friday (defined as 1) in second week of the season, the F_{ik} value should be as follows in *F* Table:

$$F_{i,2} = 1$$

The entire fixture, which is decided by the organizer of the sport event by lot, is given in a "Fixture Data Table". This table indicates the match weeks of teams. The Fixture Data Table shows the teams who play against each other in which weeks during the season and an example of this table cab be seen in Appendix A. We defined the weeks as the numbers in Fixture Data Table. The notation for this definition is shown below:

$$(Fixture\ Data)_{i,j} = k \quad (13)$$

For example, if team *i* and team *j* have a game against each other in 5th week of the season, it is shown as following in Fixture Data Table:

$$(Fixture\ Data)_{i,j} = 5$$

Moreover, there are some critical decision variables which appears as the penalties that are needed to be minimized in the objective function. There are three types of penalties defined in our model: P_{ik}^{comp}, P_{ik}^{cons}, and $P_{ik}^{sameday}$. P_{ik}^{comp} denotes the number of deficient rest days of team i compared to its competitor in week k. For

example, if team *i* and team *j* rest for 5 and 7 days respectively before their game with each other in week *k*, then this penalty occurs for team *i* and *j* in week *k* as follows: $P_{ik}^{comp} = 2$ and $P_{jk}^{comp} = 0$. This means that penalty P_{jk}^{comp} is always zero if team *j* rests more than its competitor in week *k*. P_{ik}^{cons} is number of days less than five between two consecutive games of team i in week k. For example; the penalty P_{ik}^{cons} is 2, if team *i* rests only 3 days (which is 2 days less than five) between two consecutive games in week *k-1* and *k*. Last but not least, the penalty $P_{ijk}^{sameday}$ is defined as follows:

$$P_{ijk}^{sameday} = \begin{cases} 1 & \text{if top teams } i \text{ and } j \text{ have their games in the same day of week } k \\ 0 & \text{otherwise} \end{cases}$$

Also $\omega_1, \omega_2, \omega_3$ are parameters that denote the weights in the objective function. Weights (in the given order) are assigned to each of the penalties $P_{ik}^{comp}, P_{ik}^{cons}, P_{ijk}^{sameday}$, respectively.

Organizer of a sport event must also decide the number of matches in a match day. β_d is a parameter that represents the number of maximum games allowed on match day *d*.

Two constraints (8) and (9) contain binary variables which are defined as "y_{ijk}", and these constraints also involve an arbitrarily large positive number *M*. Binary variable y_{ijk} is defined to model a set of either-or constraints in the model. For example, if y_{ijk} is equal to 1, constraint (8) becomes redundant and constraint (9) becomes active. If y_{ijk} is equal to 0, then constraint (9) becomes redundant and constraint (8) becomes active.

GDSP model, as presented, tries to find a solution which satisfy all constraints and then yields a result which has minimum sum of weighted penalties.

3.2 Game-day Scheduling Problem Considering Only League Games (GDSP-NLG)

The game-day scheduling problem (GDSP) can be modeled in either of the following two decision environments: (i) game-day scheduling of league games all at once by ignoring national cup and international fixtures (e.g. European cup), (ii) game-day scheduling of league games all at once by considering predetermined national cup and international (European cup) fixtures, only national league games (GDSP-NLG). The model with the former decision environment is labeled as GDSP-NLG model, and the model with the latter decision environment is labeled as GDSP-ALL in our research.

GDSP-NLG model can be formulated in the following manner (10):

Minimize Z

$$\omega_1 \sum_{i=1}^{n} \sum_{k \in K} P_{ik}^{comp} + \omega_2 \sum_{i=1}^{n} \sum_{k \in K} P_{ik}^{cons} + \omega_3 \sum_{i \in TopTeams} \sum_{j \in Topteams:\, i<j} \sum_{k \in K} P_{ijk}^{sameday} \quad (1)$$

Subject to

$$\sum_{d} x_{idk} = 1 \qquad \forall i \in I,\ \forall k \in K \quad (2)$$

$$x_{idk} = x_{jdk} \qquad \forall \{i, j \in I : FixtureData_{i,j} = k\},\ \forall d \in D \quad (3)$$

$$\sum_{i} x_{idk} \leq 2\, \beta_d \qquad \forall i \in I,\ \forall k \in K \quad (4)$$

$$2 \leq \sum_{d \in D} d\, x_{idk} \leq 3 \qquad \forall i \in TopTeams,\ \forall k \in K \quad (5)$$

$$P_{ik}^{comp} + \sum_{d \in D} d\, x_{idk} - \sum_{d \in D} d\, x_{id(k-1)} = P_{jk}^{comp} + \sum_{d=1}^{4} d\, x_{jdk} - \sum_{d \in D} d\, x_{jd(k-1)} \qquad \forall \{i, j \in I : i < j\},\ \forall k \in K \quad (6)$$

$$P_{ik}^{cons} + \sum_{d \in D} d\, x_{idk} - \sum_{d \in D} d\, x_{id(k-1)} + 7 \leq 5 \quad \forall i \in I,\ \forall k \in K \quad (7)$$

$$\sum_{d \in D} x_{idk} - \sum_{d \in D} x_{jdk} + 1 - P_{ik}^{sameday} \leq My_{ijk} \quad \forall i, j \in TopTeams,\ \forall k \in K \quad (8)$$

$$\sum_{d \in D} x_{jdk} - \sum_{d \in D} x_{idk} + 1 - P_{ijk}^{sameday} \leq M(1 - y_{ijk}) \quad \forall i, j \in TopTeams, \forall k \in K \quad (9)$$

Constraint (1-5) can be considered as hard constraints (which set conditions for the variables that are required to be satisfied by any means), and constraints (6-9) are soft constraints (which have some variable values that are penalized in the objective function).

The hard constraints are listed and defined in order of appearance as follows:

1- Each team must play its game at a week in only a single day. (2)
2- If team *i* and *j* have a game against each other in week *k*, their matches must be assigned to the same day. (3)
3- Number of matches on day *d* cannot exceed the maximum permissible matches in that day. (4)
4- Derbies (games between *TopTeams*) must be played on Saturday or Sunday during the season. (5)

The soft constraints are defined as follows:

1- If two teams *i* and *j* have a game against each other in a week *k*, then they should both have their previous game in week *k-1* on the same day. Otherwise, either penalty P_{ik}^{comp} or penalty P_{jk}^{comp} must get a positive value to equalize the right and left side of the equation. (6)
2- Each team should have at least five days between their consecutive games. Otherwise, penalty P_{ik}^{cons} must get a positive value to satisfy the inequality. (7)
3- We should assign the games of the *TopTeams i* and *j* to different days, unless they play against each other. Otherwise, binary penalty $P_{ijk}^{sameday}$ must get the value of 1 to satisfy the inequality. (8) & (9)

In order to maintain the validity of the soft constraints, the model will be eventually forced to generate these three types of penalties. The objective function consists of the weighted sum of all penalties. (1)

3.3 Game-day Scheduling Problem Considering All Games (GDSP-ALL)

The new GDSP-ALL model has some additions which are different from GDSP-NLG model. A few abbreviations are used in GDSP-NLG model such as F_{ik} (12) which is about league games. That abbreviation is also used for Game-Day scheduling problem. However, GDSP-ALL model needs another abbreviations. Also the new abbreviation should be different from F_{ik} which is used in model GDSP-NLG.

New parameter should be applied in GDSP-ALL such as including only match days of UEFA Champions League, UEFA Europa League and domestic trophy matches. Specialty of these matches is out of the league competition. So, we created C Table which contains UEFA Champions League matches, UEFA Europa League matches and domestic trophy matches. There are all teams match days except for league games in C Table and these matches are played in weekdays. When the team has no match in weekdays, it takes the value of an out-of-range value (which we arbitrarily defined as -100) in this C Table. If there is not any -100 in the box of C Table, that means there is a match in weekdays. So, the created C Table is shown in Appendix B and required parameter was applied such as following:

$$C_{i,k} \quad (14)$$

To explain the new parameter, for example, if team *i* has a match on Tuesday which is in weekdays in third week of the season such as UEFA Champions League match, the equation should be as:

$$C_{i,3} = -2$$

Weekday match days are represented as the numbers to define a model clearly. They are numbered such as Tuesday is equal to -2, Wednesday -1 and Thursday 0.

For many sport-scheduling applications, such as football league competitions or baseball league competitions, orderly system is necessary. This Chapter includes whole matches such as national league matches and another all matches. Considering weekday matches to ensure equality for all teams and teams' members, we need to add some constraints to GDSP-ALL model. Then a set of constraint is formulated in the GDSP-ALL.

The hard constraint is added which is about the game day's period of the team. To explain that condition; there must be at least three days between the match day of a team in weekdays (k) and its previous league match day in week (k-1). This means the added hard constraint ensures that there should be at least three days between two matches (in weekday's k and in week k-1) of the team. However, this added hard constraint is not enough for the new GDSP-ALL model. Because, the applied soft constraint set (6) of GDSP-NLG model are implemented for only national league matches which involve numbers of Fixture Data. However, the GDSP-ALL model

covers all matches. Therefore, by considering other matches such as UEFA Champions League, UEFA Europa League and local trophy matches. This constraint should be formulated again. The new hard constraint in GDSP-ALL model is defined as:

$$7 + C_{i,k} - F_{i,k-1} \geq 3 \quad (15)$$

In addition, $C_{i,k}$ (14) was applied four different ways for any team in GDSP-ALL model. Each cases and conditions of the teams who will play against each other are compared to optimize the GDSP-ALL model. For example, Galatasaray plays UEFA Europa League match on Thursday in midweek day of week *k*. However, Bursaspor has no match in this midweek and Bursaspor played its previous league match on Sunday in week *k*-1. Assume that Galatasaray (team *i*) and Bursaspor (team *j*) have game against each other on Saturday in week *k*. This means Galatasaray will be rested four days less than its competitor. As in the example, there are four different possibilities in total for team *i* and *j*, who will play against each other in week *k*:

1- $C_{i,k} = -100$ & $C_{j,k} = -100$ (neither team has a midweek game)

2- $C_{i,k} = -100$ & $C_{j,k} > -100$ (team *j* has midweek game, but team *i* has not)

3- $C_{i,k} > -100$ & $C_{j,k} > -100$ (both teams have midweek game)

4- $C_{i,k} > -100$ & $C_{j,k} = -100$ (team *i* has midweek game, but team *j* has not)

That condition is added into soft constraint set (6). Therefore, four different types of soft constraint (6) are obtained which are added to the model as soft constraint set 1, soft constraint set 2, soft constraint set 3, and soft constraint set 4.

If first condition ($C_{i,k} = -100$ & $C_{j,k} = -100$) is valid in the schedule, the soft constraint below is applied to the mathematical model:

$$P_{i,k}^{comp} + 7 + F_{i,k} - F_{i,k-1} = P_{j,k}^{comp} + 7 + F_{j,k} - F_{j,k-1} \quad (16)$$

If second condition ($C_{i,k} = -100$ & $C_{j,k} > -100$) is valid in the schedule, the soft constraint below is applied to the mathematical model:

$$P_{i,k}^{comp} + 7 + F_{i,k} - F_{i,k-1} = P_{j,k}^{comp} + F_{j,k} - C_{j,k} \quad (17)$$

If third condition ($C_{i,k} > -100$ & $C_{j,k} > -100$) is valid in the schedule, the soft constraint below is applied to the mathematical model:

$$P_{i,k}^{comp} + F_{i,k} - C_{i,k} = P_{j,k}^{comp} + F_{j,k} - C_{j,k} \quad (18)$$

If fourth condition ($C_{i,k} > -100$ & $C_{j,k} = -100$) is valid in the schedule, the soft constraint below is applied to the mathematical model:

$$P_{i,k}^{comp} + F_{i,k} - C_{i,k} = P_{j,k}^{comp} + 7 + F_{j,k} - F_{j,k-1} \qquad (19)$$

The similar process is applied to soft constraint set (7) which has to be added to GDSP-ALL model. Therefore, some modifications should be made to the model. This modified soft constraint set (7) in GDSP-NLG model is about rest days of team. In clearly, team should rest at least five days between its consecutive two matches. For example, if team *i* has a match on Monday in week *k*-1, and then if the next match of team *i* is on Saturday in week *k*, penalty will not be applied. Because, team *i* has enough rest days between its two consecutive matches. That means, soft constraint set (7) is provided, the numbers of rest days for all teams should be at least five days or more than that.

The GDSP-ALL model includes all matches which is different than GDSP-NLG model. However, soft constraint set (7) should be set in terms of GDSP-ALL model. Therefore, soft constraint set (7) is separated as two conditions:

1- $C_{i,k} > -100$ (team *i* has a midweek game in week *k*)
2- $C_{i,k} = -100$ (team *i* does not have a midweek game in week *k*)

These relationships and conditions are added to GDSP-ALL model for weekday matches of teams.

If first condition ($C_{i,k} > -100$) is valid in the schedule, the soft constraint below is applied to the mathematical model:

$$P_{i,k}^{cons} + F_{i,k} - C_{i,k} \geq 5 \qquad (20)$$

If second condition ($C_{i,k} = -100$) is valid in the schedule, the soft constraint below is applied to the mathematical model:

$$P_{i,k}^{cons} + F_{i,k} - F_{i,k-1} + 7 \geq 5 \qquad (21)$$

CHAPTER 4 - EXPERIMENTS AND RESULTS

4.1 Dataset

There are 18 teams in Turkish League (Turkish Super League). In Turkey the season of Turkish Super League (TSL) begins in August and ends in May. Home & Away fixture is applied for all 18 teams. Season consists of two periods as first period and second period. The policy of TFF (Turkish Football Federation) declares that matches are played from Friday to Monday unless there is a contrary situation. Each team plays with each its competitors for twice during the season. One match is played in home stadium and the other match is played in away stadium of the competitors. Thus, each team plays 34 matches during the season and at the end of the season totally 306 matches are played. In Turkey, matches are played under the conditions which is set by TFF. The football industry has something in wide audience's sights. Therefore, requests for broadcasters are also important to determine these criteria. Fixture is organized a few weeks before the beginning of the league matches. Game days are announced before game weeks.

The team who is the leader in the league at the end of the season, will join to UEFA Champions League. Runner-up team will join to UEFA Champions League with play-off. The team who is Turkish Cup winner will join to UEFA Europa League. The teams who are third place and fourth place in the league will join to UEFA Europa League.

4.2 Experiments

The GDSP model formulated by using an integer programming as we explained previously in two phases which are game-day scheduling problem considering only

league games (GDSP-NLG) and game-day scheduling problem considering all games (GDSP-ALL). In these two models, we focused on assignment of the match days. It means that, x_{idk} (11) and $F_{i,k}$ (12) are occured as decision variables in two models. In section 4.2.1, we compared GDSP-NLG performance in terms of the measurement performance of TFF (Turkey Football Federation). In section 4.2.2, the same process was applied to GDSP-ALL model and we compared results with TFF. However, for these two processes (GDSP-NLG and GDSP-ALL), to measure the performance of TFF, the data (match days) is received from TFF. Therefore, we assigned the game days to our models GDSP-NLG and GDSP-ALL that is why $F_{i,k}$ (12) and x_{idk} (11) are the decision variables in these two experiments. However, the GDSP model data which is received from TFF is used that $F_{i,k}$ (12) as a parameter and x_{idk} (11) as a decision variable. Also, the value of $\omega_1, \omega_2, \omega_3$ which are the weights, are equal to "1" in our mathematical model. Firstly, for all models, Table 4.2.1 is represented below which shown the schedule of season. In the Table 4.2.1, *(k,d)* is described as *week, day*. Thus, the match days of match weeks of Turkish Super League season 2013-2014 are for all teams in the league:

Table 4.2. 1: Days and Weeks Data Table

Spor Toto Super League Season 2013-2014																			
Days and Weeks Data Table																			
(k,d)		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Akhisar Belediyespor	**1**		25,2	9,2	23,1	27,2	1,3	28,2	32,3	7,3	5,1	19,3	12,4	34,3	30,2	21,3	16,4	14,3	3,4
Antalyaspor	**2**	8,3		6,4	3,2	24,3	32,2	22,3	12,3	21,4	19,2	16,3	26,2	14,2	10,4	1,1	30,4	28,2	34,3
Beşiktaş	**3**	26,3	23,1		21,3	8,4	16,2	24,3	30,3	5,3	3,3	34,2	10,3	32,2	28,2	19,1	14,4	12,4	1,3
Bursaspor	**4**	6,1	20,3	4,3		22,1	30,2	18,2	10,2	2,3	34,2	14,3	24,2	12,2	8,4	16,4	28,3	26,2	32,3
Çaykur Rizespor	**5**	10,3	7,3	25,2	5,3		34,2	26,2	14,2	23,3	21,1	1,2	28,2	16,1	12,2	3,4	32,3	30,3	19,4
Elazığspor	**6**	18,3	15,2	33,3	13,1	17,2		8,2	22,4	31,3	29,4	9,2	2,3	24,2	20,3	11,1	6,3	4,3	27,2
Eskişehirspor	**7**	11,1	5,2	7,2	1,3	9,3	25,3		19,2	3,1	16,3	27,4	13,3	23,2	32,2	31,3	21,4	34,1	29,3
Fenerbahçe	**8**	15,1	29,3	13,2	27,4	31,3	5,2	2,2		11,3	9,1	23,2	33,1	21,3	17,3	25,3	3,2	18,4	7,3
Galatasaray	**9**	24,2	4,1	22,2	19,3	6,2	14,1	20,2	28,3		1,4	32,2	8,2	30,2	26,2	34,2	12,2	10,1	16,3
Gaziantepspor	**10**	22,2	2,2	20,1	17,2	4,2	12,3	33,3	26,4	18,3		30,2	6,2	28,1	24,3	15,3	10,4	8,3	14,3
Gençlerbirliği	**11**	2,1	33,2	17,1	31,1	18,2	26,3	10,4	6,3	15,3	13,2		20,4	8,2	4,3	29,3	24,3	22,3	11,3
Karabükspor	**12**	29,2	9,2	27,1	7,1	11,2	19,3	30,4	16,3	25,1	23,2	3,3		1,2	14,3	5,1	34,3	32,2	21,2
Kasımpaşa	**13**	17,1	31,3	15,2	29,2	33,3	7,3	6,3	4,4	13,3	11,2	25,2	18,1		2,2	27,1	22,3	20,1	9,4
Kayserispor	**14**	13,2	27,4	11,2	25,4	29,2	3,2	15,2	34,1	9,3	7,2	21,2	31,3	19,2		23,3	1,4	16,3	5,4
Kayseri Erciyesspor	**15**	4,3	18,3	2,4	33,3	20,2	28,3	14,4	8,3	17,2	32,2	12,3	22,2	10,2	6,4		26,3	24,2	30,1
Sivasspor	**16**	33,3	13,1	31,3	11,2	15,2	23,3	4,3	20,3	29,2	27,2	7,3	17,3	5,2	18,3	9,1		2,3	25,3
Torku Konyaspor	**17**	31,3	29,1	29,1	9,3	13,4	21,4	17,3	1,2	27,2	25,3	5,2	15,1	3,1	33,3	7,2	19,3		23,3
Trabzonspor	**18**	20,3	17,3	18,2	15,4	2,4	10,3	12,3	24,4	33,3	31,2	28,4	4,2	26,1	22,3	13,3	8,3	6,3	

For example, as in Table 4.2.1, it is clear that Akhisar Belediyespor (home) and Antalyaspor (away) have a game against each other on Saturday in 25th week of season

2013-2014 which is showed as (25,2). That Table 4.2.1 is applied for all GDSP models which are game-day scheduling problem considering only league games (GDSP-NLG), game-day scheduling problem considering all games (GDSP-ALL). Also the Table 4.2.1 is used for the other two experiments of (GSDP-NLG) and (GDSP-ALL) which contain data of Turkey Football Federation (TFF).

In Chapter 4.2.1 and 4.2.2, considering all information, TFF's performance is measured and compared with our performance. The computation time was small ranging from 1.61 to 9.58 seconds on a 1.60 GHz Intel Core i5 computer. The C++ codes implements the mathematical model and then problems are solved the IP formulation with ILOG CPLEX. We calibrated the parameters of CPLEX to optimize performance.

4.2.1 Game-day Scheduling Problem Considering Only League Games (GDSP-NLG)

GDSP-NLG model consists two parts. First part, we decided about match days. It means that x_{idk} and $F_{i,k}$ are decision variables. Second part of GDSP-NLG is about match days which are received from TFF schedule. It means that x_{idk} is a decision variable and $F_{i,k}$ is a parameter in second part of GDSP-NLG. The purpose of second part is performance measurement of TFF. Two parts of GDSP-NLG are solved and results are compared to each other.

First part of GDSP-NLG model is solved and the following solution is shown in Table 4.2.1.1. The all penalties which are ($P_{ik}^{comp}, P_{ik}^{cons}, P_{ijk}^{sameday}$) as shown below, are obtained by using the integer programming in GDSP-NLG model:

Table 4.2.1. 1: The Results of Penalties for GDSP-NLG

P_Comparable	P_Consecutive	P_Sameday	TOTAL PENALTIES
132	0	68	200

The value of P_{ik}^{comp} which is equal to 132, is the value of mentioned penalties or deviation variable P_{ik}^{comp} . This penalty means that number of deficient rest days of team i compared to its competitor in week k. In Table 4.2.1.1, P_{ik}^{cons} which is equal to 0 is represented the number of days less than five between two consecutive games of team i in week k. The value of last penalty $P_{ijk}^{sameday}$ is equal to 68 which represented that top teams i and j have their games in the same day of week k. The total penalty is equal to 200 for the first part of GDSP-NLG model. However, when we compared our solution with respect to data of TFF, which is used $F_{i,k}$ (12) as the parameter and x_{idk} (11) as the decision variable, definitely the reported results of integer programming model are different than the first part of GDSP-NLG. Also, all penalty results for GDSP-NLG model are shown in Appendix D.

According to the following results of penalties (or deviation variable) of second part of GDSP-NLG model which contains Turkey Football Federation (TFF) data is shown in Table 4.2.1.2 and these results are shown in Appendix E:

Table 4.2.1. 2: The Results of Penalties for GDSP-NLG which is using TFF Data

P_Comparable	P_Consecutive	P_Sameday	TOTAL PENALTIES
294	2	56	352

The following Table 4.2.1.3 represents results that first part of GDSP-NLG model is equal to 200 and second part of GDSP-NLG is equal to 352:

Table 4.2.1. 3: Our Model Performance and TFF Performance for GDSP-NLG Model

	P_Comparable	P_Consecutive	P_Sameday	TOTAL PENALTIES
TFF	294	2	56	352
OUR RESULT	132	0	68	200
PERCENTAGE	55,10%	0,00%	-21,43%	43,18%

If these results are compared each other, the first part of GDSP-NLG model gives 43% better results in total than the second part which involves TFF's data. Obviously the difference is clear between the two reported results as $P_{ik}^{comp}, P_{ik}^{cons}, P_{ijk}^{sameday}$.

4.2.2 Game-day Scheduling Problem Considering All Games (GDSP-ALL)

GDSP-ALL is separated as two parts in section 4.2.2. For the first part of GDSP-ALL, we decided the match days and for the second part, we received match days from TFF. The first and second part have been established for the same purpose in both models which are GDSP-NLG and GDSP-ALL. The only difference between GDSP-NLG model and GDSP-ALL model is that GDSP-ALL contains all organizations such as UEFA Champions League, UEFA European League and the Turkish Cup. That means, GDSP-NLG considers only league matches. The reported penalties of first part of GDSP-ALL model are shown below in Table 4.2.2.1 and all penalty results are shown in Appendix F:

Table 4.2.2. 1: The Results of Penalties for GDSP-ALL

P_Comparable	P_Consecutive	P_Sameday	TOTAL PENALTIES
281	133	72	486

The second part of GDSP-ALL model is solved as the same procedure of GDSP-NLG's second part. The integer programming reported values of $P_{ik}^{comp}, P_{ik}^{cons}, P_{ijk}^{sameday}$ as penalties in second part of model GDSP-ALL results are shown below and all penalty results for second part of GDSP-ALL model are shown in Appendix G:

Table 4.2.2. 2: The Results of Penalties for GDSP-ALL by using TFF Data

P_Comparable	P_Consecutive	P_Sameday	TOTAL PENALTIES
433	118	56	607

To explain two approaches, x_{idk} (11) and $F_{i,k}$ (12) are used as the decision variables in first part of GDSP-ALL. However, $F_{i,k}$ (12) is used as the parameter and x_{idk} (11) is used as the decision variable in second part of GDSP-ALL model which receives the data from TFF as the same implementation in GDSP-NLG model.

So according to the integer programming solution reports of penalties, the results of first part of GDSP-ALL model is equal to 486 and the results of second part of GDSP-ALL model is equal to 607. When two implementations are compared, first part of GDSP-ALL model gives 19,93 % better results in total than the second part which is received data from TFF. The all results are shown in Table 4.2.2.3:

Table 4.2.2. 3: Our Model Performance and TFF Performance for GDSP-ALL Model

	P_Comparable	**P_Consecutive**	**P_Sameday**	**TOTAL PENALTIES**
TFF	433	118	56	607
OUR RESULT	281	133	72	486
PERCENTAGE	35,10%	-12,71%	-28,57%	19,93%

CHAPTER 5 - IMPLEMENTATIONS

5.1 Implementing GDSP in Real Time

This thesis based on the real time applications of GDSP with real data of Turkish Super League season 2013-2014. In this Chapter, these applications will be described and previously solved problem which is second part of GDSP-ALL will be resolved in real time with real data.

In this application, for every announced match date, the system will be stopped. According to real time data, the system will be restarted for 10 times in GDSP model. By using this process, the model is assigned match days in real time with real values.

Operation mode of the established models are shown as follows:

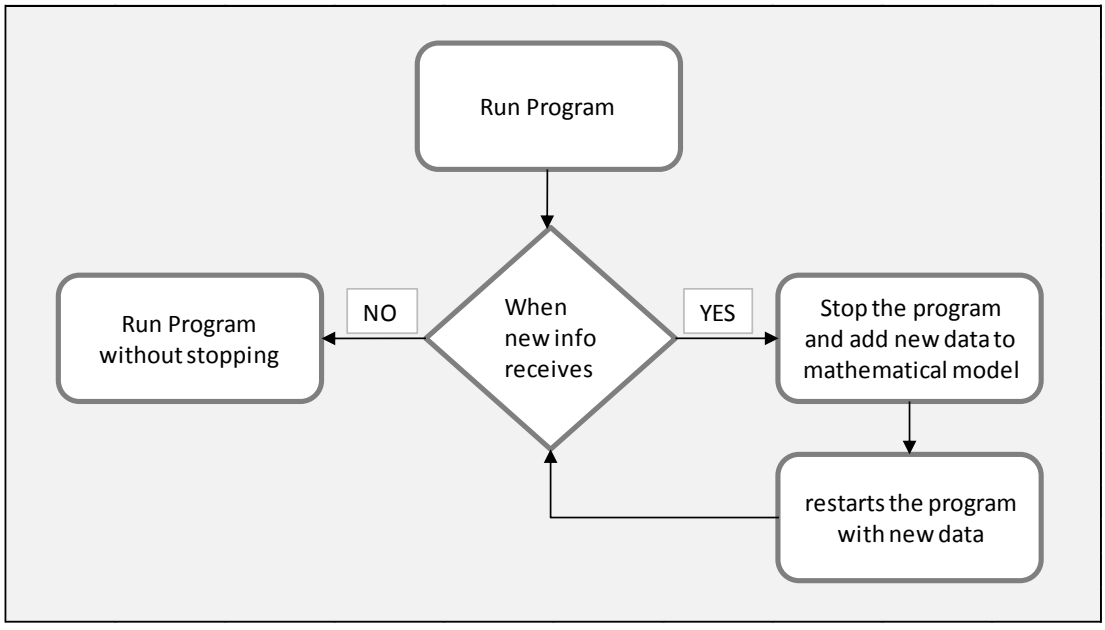

Figure 5. 1: The Operation Mode of Real Time Model

The new constraint is added to the old GDSP model as hard constraint. For example to explain the new added hard constraint, if the new information is about match days in second week, the system should save fixture until second week and it must restart from second week to the end of the season. The added hard constraint provides to stop the system when the new information is received. For this process, FX Table is created to record fixed match days of weeks and that table has been updated when the system is restarted for each time. This operation is necessary to write fixed match days of weeks to the FX Table. This new hard constraint has been synchronized with $F_{i,k}$ and added to the mathematical model. Then the new mathematical model of GDSP prevents the changing assigning days in FX Table.

The aim of the real time application is that minimize the difference of teams rest day. For example, if two teams *i* and *j* have a game against each other on Friday of week k, their next matches will be assigned equitable in week *k+1*. If that cannot be satisfied, a penalty should be applied.

Turkish Super League (TSL) fixture was determined in July 17, 2013. The mathematical model is assigned the match days of all teams and they were known their fixture on that date. However, it would be suitable if they have no any other non-league matches.

These non-league matches are belong organizations which cover UEFA Champions League, UEFA European League and the Turkish Cup which is called Ziraat Turkish Cup that includes only Turkish teams.

At the end of the season 2012-2013, only Galatasaray joined UEFA Champions League group matches and only Trabzonspor joined UEFA European League group matches for season 2013-2014.

The announced dates of season 2013-2014 are shown below:

Announced Dates		Announced Matches
1	24 June, 2013 - Fixtures not determined	UEFA European League
2	29 August, 2013	Champions League, UEFA European League
3	17 September, 2013	Ziraat Turkish Cup, 2nd Tour
4	8 October, 2013	Ziraat Turkish Cup, 3th Tour
5	11 November, 2013	Ziraat Turkish Cup, 4th Tour
6	6 December, 2013	Ziraat Turkish Cup, 5th Tour
7	16 December, 2013	Champions League, UEFA European League
8	25 December, 2013	Ziraat Turkish Cup, Groups
9	13 February, 2014	Ziraat Turkish Cup, Semi Final
10	17 April, 2014	Ziraat Turkish Cup, Final

Champions League and UEFA European League	
29 August, 2013	**16 December, 2013**
Galatasaray, 5TH Week, Tuesday	Galatasaray, 23TH Week, Wednesday
Galatasaray, 7TH Week, Wednesday	Galatasaray, 26TH Week, Tuesday
Galatasaray, 9TH Week, Wednesday	Trabzonspor, 22TH Week, Thursday
Galatasaray, 11TH Week, Tuesday	Trabzonspor, 23TH Week, Thursday
Galatasaray, 13TH Week, Wednesday	
Galatasaray, 15TH Week, Tuesday	
Trabzonspor, 5TH Week, Thursday	
Trabzonspor, 7TH Week, Thursday	
Trabzonspor, 9TH Week, Thursday	
Trabzonspor, 11TH Week, Thursday	
Trabzonspor, 13TH Week, Thursday	
Trabzonspor, 15TH Week, Thursday	

Champions League and UEFA European League	
29 August, 2013	**16 December, 2013**
Galatasaray, 5TH Week, Tuesday	Galatasaray, 23TH Week, Wednesday
Galatasaray, 7TH Week, Wednesday	Galatasaray, 26TH Week, Tuesday
Galatasaray, 9TH Week, Wednesday	Trabzonspor, 22TH Week, Thursday
Galatasaray, 11TH Week, Tuesday	Trabzonspor, 23TH Week, Thursday
Galatasaray, 13TH Week, Wednesday	
Galatasaray, 15TH Week, Tuesday	
Trabzonspor, 5TH Week, Thursday	
Trabzonspor, 7TH Week, Thursday	
Trabzonspor, 9TH Week, Thursday	
Trabzonspor, 11TH Week, Thursday	
Trabzonspor, 13TH Week, Thursday	
Trabzonspor, 15TH Week, Thursday	

Local Thropy Games	
17 September, 2013 - Ziraat Turkish Cup - 2ND Tour	**8 October, 2013 - Ziraat Turkish Cup - 3TH Tour**
Akhisar Belediyespor, 6TH Week, Tuesday	Akhisar Belediyespor, 10TH Week, Wednesday
Antalyaspor, 6TH Week, Tuesday	Antalyaspor, 10TH Week, Wednesday
Elazığspor, 6TH Week, Wednesday	Çaykur Rizespor, 10TH Week, Wednesday
Eskişehirspor, 6TH Week, Wednesday	Elazığspor, 10TH Week, Tuesday
Gaziantepspor, 6TH Week, Tuesday	Eskişehirspor, 10TH Week, Wednesday

Gençlerbirliği, 6TH Week, Wednesday	Gaziantepspor, 10TH Week, Thursday
Karabükspor, 6TH Week, Tuesday	Gençlerbirliği, 10TH Week, Thursday
Kayserispor, 6TH Week, Thursday	Karabükspor, 10TH Week, Wednesday
Kayseri Erciyesspor, 6TH Week, Wednesday	Kayserispor, 10TH Week, Thursday
Torku Konyaspor, 6TH Week, Thursday	Kayseri Erciyesspor, 10TH Week, Wednesday
Çaykur Rizespor, 7TH Week, Tuesday	Sivasspor, 10TH Week, Tuesday
Kasımpaşa, 7TH Week, Thursday	Kasımpaşa, 11TH Week, Wednesday
Sivasspor, 7TH Week, Wednesday	Torku Konyaspor, 11TH Week, Wednesday

11 November, 2013 - Ziraat Turkish Cup - 4TH Tour	**6 December, 2013 - Ziraat Turkish Cup - 5TH Tour**
Akhisar Belediyespor, 14TH Week, Wednesday	Akhisar Belediyespor, 16TH Week, Thursday
Antalyaspor, 14TH Week, Tuesday	Antalyaspor, 16TH Week, Wednesday
Beşiktaş, 14TH Week, Thursday	Bursaspor, 16TH Week, Thursday
Bursaspor, 14TH Week, Wednesday	Elazığspor, 16TH Week, Tuesday
Elazığspor, 14TH Week, Tuesday	Eskişehirspor, 16TH Week, Thursday
Eskişehirspor, 14TH Week, Thursday	Galatasaray,16TH Week, Wednesday
Fenerbahçe, 14TH Week, Wednesday	Karabükspor, 16TH Week, Tuesday
Galatasaray, 14TH Week, Tuesday	Kayserispor, 16TH Week, Wednesday
Gaziantepspor, 14TH Week, Wednesday	Kayseri Erciyesspor, 16TH Week, Thursday
Gençlerbirliği, 14TH Week, Wednesday	Sivasspor, 16TH Week, Thursday

Karabükspor, 14TH Week, Thursday	
Kayserispor, 14TH Week, Thursday	
Kayseri Erciyesspor, 14TH Week, Thursday	
Sivasspor, 14TH Week, Wednesday	
Trabzonspor, 14TH Week, Wednesday	

25 December, 2013 - Ziraat Turkish Cup – Groups
Akhisar Belediyespor, 18TH Week, Wednesday
Antalyaspor, 18TH Week, Wednesday
Bursaspor, 18TH Week, Wednesday
Elazığspor, 18TH Week, Wednesday
Eskişehirspor, 18TH Week, Wednesday
Galatasaray, 18TH Week, Wednesday
Sivasspor, 18TH Week, Wednesday
Akhisar Belediyespor, 19TH Week, Thursday
Antalyaspor, 19TH Week, Wednesday
Bursaspor, 19TH Week, Wednesday
Elazığspor, 19TH Week, Wednesday
Eskişehirspor, 19TH Week, Wednesday
Galatasaray, 19TH Week, Wednesday
Sivasspor, 19TH Week, Thursday
Akhisar Belediyespor, 20TH Week, Wednesday
Antalyaspor, 20TH Week, Wednesday
Bursaspor, 20TH Week, Thursday
Elazığspor, 20TH Week, Wednesday
Eskişehirspor, 20TH Week, Wednesday
Galatasaray, 20TH Week, Wednesday
Sivasspor, 20TH Week, Thursday
Akhisar Belediyespor, 21TH Week, Wednesday
Antalyaspor, 21TH Week, Wednesday

Bursaspor, 21TH Week, Wednesday
Elazığspor, 21TH Week, Wednesday
Eskişehirspor, 21TH Week, Wednesday
Galatasaray, 21TH Week, Wednesday
Sivasspor, 21TH Week, Wednesday

13 February, 2014 - Ziraat Turkish Cup - Semi Finals
Antalyaspor, 27TH Week, Wednesday
Bursaspor, 27TH Week, Tuesday
Eskişehirspor, 27TH Week, Wednesday
Galatasaray, 27TH Week, Tuesday
Antalyaspor, 30TH Week, Thursday
Bursaspor, 30TH Week, Wednesday
Eskişehirspor, 30TH Week, Thursday
Galatasaray, 30TH Week, Wednesday

17 April, 2014 - Ziraat Turkish Cup – Finals
Eskişehirspor, 33TH Week, Wednesday
Galatasaray, 33TH Week, Wednesday

(Teams in Turkish Super League join to Turkish Cup at second tour.)

5.2 Results

This thesis based on the GDSP model which is applied in real time with real data of the season 2013-2014. According to the announced match days, the system has been restarted for 10 times for Turkish Super League in season 2013-2014. Before each

restarts, C Table which includes non-league matches, is updated. The last information which is announcement of match days, is received at 30th week of season 2013-2014. When mathematical model is run from 1st week to 30th week with all synchronized data, all penalties can be obtained as results for 34 weeks in Table 5.2.1:

Table 5.2. 1: Penalties for Real Time Application Performance of GDSP Model

	P_Comparable	P_Consecutive	P_Sameday	TOTAL PENALTIES
TFF	433	118	56	607
OUR RESULT	323	149	92	564
PERCENTAGE	25,40%	-26,27%	-64,29%	7,08%

According to the season 2013-2014, results in Table 5.2.1, applied mathematical model gives 7.08 % better results in total than the TFF's model. In addition, our mathematical model is updated to FX Table and the final FX Table is shown below:

Fx TABLE

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	Akhisar Belediyespor	4	3	3	3	1	3	2	2	3	3	2	3	3	3	3	2	1	3	3	2	2	3	3	2	3	3	3	2	4	3	3	2	2	1
2	Antalyaspor	2	2	2	2	2	2	2	2	3	4	4	2	2	2	1	4	3	2	2	3	3	2	3	2	3	3	2	3	3	2	2	1	3	3
3	Beşiktaş	2	3	2	3	3	2	2	2	3	3	3	2	2	2	3	3	3	2	2	3	2	2	3	2	3	3	2	3	3	2	2	2	2	2
4	Bursaspor	2	1	2	3	3	3	3	3	1	2	1	3	1	4	3	3	2	3	2	3	2	3	3	3	2	3	2	4	2	4	2	3	3	3
5	Çaykur Rizespor	3	3	2	3	3	1	2	2	2	3	3	2	4	2	2	2	3	2	2	3	2	3	4	2	3	3	3	3	3	2	3	2	1	4
6	Elazığspor	4	3	3	2	3	2	4	2	2	2	2	3	1	2	1	3	3	3	3	2	3	2	2	2	3	2	3	2	2	4	2	1	2	4
7	Eskişehirspor	2	2	2	2	2	2	2	2	2	3	2	3	3	3	2	3	2	3	3	2	3	2	3	2	3	3	3	2	2	3	3	3	3	2
8	Fenerbahçe	3	2	3	2	3	3	3	3	2	2	3	2	2	2	3	2	2	3	3	3	3	2	2	3	2	2	2	3	3	2	3	2	2	3
9	Galatasaray	2	1	2	2	3	1	2	2	3	2	3	2	2	2	3	3	3	3	2	2	3	2	4	2	1	2	1	3	2	2	2	2	3	2
10	Gaziantepspor	2	2	2	3	1	4	2	3	2	3	2	3	3	3	4	3	2	3	2	3	2	3	3	3	2	2	2	2	2	3	3	3	3	3
11	Gençlerbirliği	3	3	3	4	2	3	3	4	2	3	2	4	3	4	3	4	3	2	3	2	4	4	2	4	3	2	3	2	3	3	2	2	3	2
12	Karabükspor	3	3	3	3	2	4	3	2	3	3	3	3	3	3	2	2	2	4	3	2	2	3	3	3	1	3	2	3	4	3	4	3	2	3
13	Kasımpaşa	3	2	4	2	4	2	4	4	3	2	2	3	2	2	3	2	1	4	3	4	3	2	3	2	3	2	3	2	2	2	2	2	1	1
14	Kayserispor	3	2	3	4	3	3	2	3	3	4	3	2	3	3	2	2	2	2	3	2	4	3	2	3	2	2	2	3	3	3	4	3	2	3
15	Kayseri Erciyesspor	2	3	2	3	2	3	3	3	2	2	2	4	3	3	4	3	3	2	2	3	2	3	2	3	2	1	3	2	3	3	3	3	3	2
16	Sivasspor	3	2	3	2	4	2	3	3	2	3	1	2	2	2	2	2	2	2	4	3	3	2	2	4	2	1	2	4	2	2	2	2	2	3
17	Torku Konyaspor	3	2	4	2	2	3	3	3	1	2	4	2	4	3	2	2	2	3	4	4	3	4	2	3	2	3	1	3	3	2	3	3	2	2
18	Trabzonspor	2	3	3	3	3	3	3	3	3	2	2	3	3	3	3	3	3	2	2	2	2	3	2	3	2	2	3	2	2	3	3	3	3	3

Also, assignment of match days from 1st week to 34th week and the last update (from 1st week to 30th week) are shown in Appendix H. The following Table 5.2.2 shows all results of experiments:

Table 5.2. 2: Total Results of Performance of GDSP Model

	Total Penalties of GDSP-NLG	Total Penalties of GDSP-ALL	Total Penalties of Real Time Application
TFF	352	607	607
OUR RESULT	200	486	564
PERCENTAGE	43,18%	19,93%	7,08%

The Table 5.2.2 indicates, when all comparisons are made, it is clear to see that our GDSP model always gives better results.

GDSP-NLG model includes only national league games, GDSP-ALL model includes all games such as UEFA Champions League, UEFA Europa League and domestic trophy matches. Also, the most comprehensive model is real time application of GDSP model. There is not any weekday's matches of teams in GDSP-NLG model. However, GDSP-ALL model focuses on both weekdays and weekend matches of teams. In the real time application, the previous solved problem of GDSP-ALL model resolved with real time data. That is why there are descending sort of performances with respect to total penalties from GDSP-NLG model to real time application.

To evaluate the real time application performance of GDSP model, relative MIP gap tolerance and absolute MIP gap tolerance are applied as 25% in OPL model (for difference between current best integer solution and optimal value of IP relaxation).

CHAPTER 6 - CONCLUSION

6.1 Summary of the Research

Our model is run for Turkish Super League (TSL) and the value of $\omega_1, \omega_2, \omega_3$ which are the weights is applied "1" to our mathematical model. Our first integer programming approach GDSP-NLG model was compared to GDSP-NLG which is used data by Turkish Football Federation (TFF) was explained in section 4.2.1. As the same way, GDSP-ALL model was compared to GDSP-ALL which is used data by Turkish Football Federation (TFF) in section 4.2.2. Lastly, modifications were made to GDSP-ALL model which includes TFF's data and this model are resolved by real time application in section 5.1. Then, all results were compared to each other in section 5.2.

In Chapter 5, for the real time application, the tolerances of relative MIP gap and absolute MIP gap are applied as 25%. Because, if we decided that the tolerance is applied as 100%, the program would need more time to obtain the optimal solution. Therefore, we decided that the tolerances should be 25%. That is why we obtained the optimal solution for real time application performance of GDSP model as 7,08%.

As it is shown in the results of tables, our models GDSP-NLG and GDSP-ALL are influential for solving larger problems which are more complicated than model of Turkish Football Federation (TFF). GDSP model consists of two parts which are GDSP-NLG and GDSP-ALL, and these models prove to be more useful and more advantageous. The specifications of the model which is used by Turkish Football Federation (TFF) can be developed to be more efficient at least GDSP models.

6.2 Opportunities for Future Work

The purpose of this paper is to evaluate integer programming as a solution methodology for the sport scheduling problem. As mentioned before in general of this research, the equity is fully applicable for all teams. If schedule is not understandable and clear, there might be many irregularities in the league. This is quite normal to be criticized these irregularities. It is important that integer programming should be effectively applied to real organization schedule such as Turkish League.

According to World league ranks of International Federation of Football History & Statistics (IFFHS), one of the most important leagues such as La Liga (Spanish first division), Serie A (Italian first division), Barclays Premier League (England Premiere League, EPL) and Bundesliga (German first division). The point of these leagues, there are 20 competitors in their competitions and they play their league matches even on weekdays if there is not any non-league matches. Our general mathematical model can be applied for these kind of leagues.

For example, the international competitions such as FIFA World Cup, UEFA European Championship (commonly referred to as UEFA Euro 2016 or simply Euro 2016 for the closest tournament), The Copa América (South American Football Championship - Campeonato Sud Americano de Football in Spanish), and the assignment of schedule is the most important thing for the organizations. The schedule planning of organizations must be equal to each teams for their rest days, travelling, and training schedule.

In this research, we focused on sport scheduling. However, scheduling is the most important situation for all organization such as nurse schedule in hospitals, lecture schedules for instructors and students in universities, and for the military organizations. These kind of organizations need an equal schedule. Therefore, mathematical modeling method and optimization can be applied for these kind of organizations.

A user-friendly component must be located for all system. Even if integer programming software has developed, specific software package would be still necessary for solving a specific problem. Commercial packages such as OPL Studio can be helpful to design the application, as integrating mathematical programming.

CHAPTER 7 - APPENDICES

APPENDIX A

Fixture Data Table

HOME		AWAY																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Akhisar Belediyespor		25	9	23	27	1	28	32	7	5	19	12	34	30	21	16	14	3
2	Antalyaspor	8		6	3	24	32	22	12	21	19	16	26	14	10	1	30	28	34
3	Beşiktaş	26	23		21	8	16	24	30	5	3	34	10	32	28	19	14	12	1
4	Bursaspor	6	20	4		22	30	18	10	2	34	14	24	12	8	16	28	26	32
5	Çaykur Rizespor	10	7	25	5		34	26	14	23	21	1	28	16	12	3	32	30	19
6	Elazığspor	18	15	33	13	17		8	22	31	29	9	2	24	20	11	6	4	27
7	Eskişehirspor	11	5	7	1	9	25		19	3	16	27	13	23	32	31	21	34	29
8	Fenerbahçe	15	29	13	27	31	5	2		11	9	23	33	21	17	25	3	18	7
9	Galatasaray	24	4	22	19	6	14	20	28		1	32	8	30	26	34	12	10	16
10	Gaziantepspor	22	2	20	17	4	12	33	26	18		30	6	28	24	15	10	8	14
11	Gençlerbirliği	2	33	17	31	18	26	10	6	15	13		20	8	4	29	24	22	11
12	Karabükspor	29	9	27	7	11	19	30	16	25	23	3		1	14	5	34	32	21
13	Kasımpaşa	17	31	15	29	33	7	6	4	13	11	25	18		2	27	22	20	9
14	Kayserispor	13	27	11	25	29	3	15	34	9	7	21	31	19		23	1	16	5
15	Kayseri Erciyesspor	4	18	2	33	20	28	14	8	17	32	12	22	10	6		26	24	30
16	Sivasspor	33	13	31	11	15	23	4	20	29	27	7	17	5	18	9		2	25
17	Torku Konyaspor	31	11	29	9	13	21	17	1	27	25	5	15	3	33	7	19		23
18	Trabzonspor	20	17	18	15	2	10	12	24	33	31	28	4	26	22	13	8	6	

C[i][k] Table

C TABLE

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	Akhisar Belediyespor	-100	-100	-100	-100	-100	-2	-100	-100	-100	-1	-100	-100	-100	-1	-100	0	-100	-1	0	-1	-1	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
2	Antalyaspor	-100	-100	-100	-100	-100	-2	-100	-100	-100	-1	-100	-100	-100	-2	-100	-1	-100	-1	-1	-1	-1	-100	-100	-100	-100	-100	-1	-100	-100	0	-100	-100	-100	-100
3	Beşiktaş	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	0	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
4	Bursaspor	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-1	-100	0	-100	-1	-1	0	-1	-100	-100	-100	-100	-100	-2	-100	-100	-1	-100	-100	-100	-100
5	Çaykur Rizespor	-100	-100	-100	-100	-100	-100	-2	-100	-100	-1	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
6	Elazığspor	-100	-100	-100	-100	-100	-1	-100	-100	-100	-2	-100	-100	-100	-2	-100	-2	-100	-1	-1	-1	0	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
7	Eskişehirspor	-100	-100	-100	-100	-100	-1	-100	-100	-100	-1	-100	-100	-100	0	-100	0	-100	-1	-1	-1	-1	-100	-100	-100	-100	-100	-1	-100	-100	0	-100	-100	-1	-100
8	Fenerbahçe	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-1	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
9	Galatasaray	-100	-100	-100	-100	-2	-100	-1	-100	-1	-100	-2	-100	-1	-2	-2	-1	-100	-1	-1	-1	-1	-100	-1	-100	-100	-2	-2	-100	-100	-1	-100	-100	-1	-100
10	Gaziantepspor	-100	-100	-100	-100	-100	-2	-100	-100	-100	0	-100	-100	-100	-1	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
11	Gençlerbirliği	-100	-100	-100	-100	-100	-1	-100	-100	-100	0	-100	-100	-100	-1	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
12	Karabükspor	-100	-100	-100	-100	-100	-2	-100	-100	-100	-1	-100	-100	-100	0	-100	-2	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
13	Kasımpaşa	-100	-100	-100	-100	-100	-100	0	-100	-100	-100	-1	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
14	Kayserispor	-100	-100	-100	-100	-100	0	-100	-100	-100	0	-100	-100	-100	0	-100	-1	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
15	Kayseri Erciyesspor	-100	-100	-100	-100	-100	-1	-100	-100	-100	-1	-100	-100	-100	0	-100	0	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
16	Sivasspor	-100	-100	-100	-100	-100	-100	-1	-100	-100	-2	-100	-100	-100	-1	-100	0	-100	-1	0	0	-1	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
17	Torku Konyaspor	-100	-100	-100	-100	-100	0	-100	-100	-100	-100	-1	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
18	Trabzonspor	-100	0	0	-100	0	-100	0	-100	0	-100	0	-100	0	-1	0	-100	-100	-100	-100	-100	-100	0	0	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100

APPENDIX C

F[i][k] Table

F TABLE

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	Akhisar Belediyespor	3	1	4	2	1	1	3	3	2	3	1	4	2	3	1	4	1	3	3	3	3	2	1	2	2	3	2	2	2	2	3	3	3	3
2	Antalyaspor	1	2	2	1	2	4	3	3	2	4	3	3	1	2	2	3	3	3	2	3	4	3	1	3	2	2	4	2	3	4	3	2	2	3
3	Beşiktaş	3	4	3	3	3	4	2	4	2	3	2	4	2	4	2	2	1	2	1	1	3	2	1	3	2	3	1	2	1	3	3	2	3	2
4	Bursaspor	3	3	2	3	3	1	1	4	3	2	2	2	1	3	4	4	2	2	3	3	3	1	1	2	4	2	4	3	2	2	1	3	3	2
5	Çaykur Rizespor	2	4	4	2	3	2	3	4	3	3	2	2	4	2	2	1	2	2	4	2	1	1	3	3	2	2	2	2	2	3	3	3	3	2
6	Elazığspor	3	3	2	3	2	3	3	2	2	3	1	3	1	1	2	2	2	3	3	3	4	4	3	2	3	3	2	3	4	2	3	2	3	2
7	Eskişehirspor	3	2	1	3	2	3	2	2	3	4	1	3	3	4	2	3	3	2	2	2	4	3	2	3	3	2	4	2	3	4	3	2	3	1
8	Fenerbahçe	2	2	2	4	2	3	3	3	1	2	3	3	2	2	1	3	3	4	2	3	3	4	2	4	3	4	4	3	3	3	3	3	1	1
9	Galatasaray	4	3	1	1	3	2	3	2	3	1	3	2	3	1	3	3	2	3	3	2	4	2	3	2	1	2	2	3	2	2	3	2	3	2
10	Gaziantepspor	4	2	3	2	1	2	2	3	1	4	2	3	2	3	3	3	2	3	2	1	1	2	2	3	3	4	2	1	4	2	2	2	3	2
11	Gençlerbirliği	2	1	3	3	2	3	3	2	2	4	3	3	2	3	3	3	1	2	3	4	2	3	2	3	2	3	4	4	3	2	1	2	2	2
12	Karabükspor	2	3	3	2	1	2	1	2	2	3	2	4	3	3	1	3	3	1	3	4	2	2	2	2	1	2	1	2	2	4	3	2	1	3
13	Kasımpaşa	2	2	1	4	2	3	3	2	4	2	2	2	3	2	2	1	1	1	2	1	3	3	2	2	2	1	1	1	2	2	3	2	3	3
14	Kayserispor	4	2	2	3	4	4	2	4	3	4	2	2	2	3	2	3	3	3	2	3	2	3	3	3	4	2	4	2	2	2	3	2	3	1
15	Kayseri Erciyesspor	1	4	4	2	1	4	2	3	1	2	1	3	3	4	3	4	2	3	1	2	3	2	3	2	3	3	1	3	3	1	3	2	3	2
16	Sivasspor	4	3	2	3	2	3	3	3	1	4	2	2	1	4	2	4	3	3	3	3	4	3	3	3	3	3	2	3	2	4	3	3	3	3
17	Torku Konyaspor	2	3	1	3	2	3	2	3	3	1	3	4	4	3	1	3	3	4	3	1	4	3	3	2	3	2	2	2	1	3	3	2	3	1
18	Trabzonspor	3	4	4	2	4	3	3	3	4	3	3	3	3	3	4	3	3	2	4	3	2	3	3	4	3	1	2	4	3	1	2	3	3	3

APPENDIX D

Penalty Results for GDSP-NLG Model

P_Comp

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	TOPLAM
Akhisar Belediyespor	1	0	0	0	0	0	1	0	0	1	0	0	0	2	0	0	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1	9
Antalyaspor	2	0	1	0	0	1	0	0	0	1	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	9
Beşiktaş	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Bursaspor	4	0	2	0	0	0	0	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	10
Çaykur Rizespor	5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
Elazığspor	6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	1	0	0	0	5
Eskişehirspor	7	0	0	0	0	0	0	0	1	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	7
Fenerbahçe	8	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4
Galatasaray	9	0	0	0	1	1	0	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7
Gaziantepspor	10	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	5
Gençlerbirliği	11	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	2	1	0	1	0	0	0	0	0	0	0	7
Karabükspor	12	0	1	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	1	0	1	1	0	0	0	1	0	0	1	0	1	0	12
Kasımpaşa	13	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	2	1	1	0	0	0	1	0	0	0	0	0	0	1	2	0	0	12
Kayserispor	14	0	0	1	2	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	8
Kayseri Erciyesspor	15	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	1	0	0	0	0	0	1	0	6
Sivasspor	16	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	1	0	1	0	0	0	0	2	10
Torku Konyaspor	17	0	0	1	0	0	1	0	0	0	0	0	1	0	0	2	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	9
Trabzonspor	18	0	0	0	1	0	0	0	0	0	0	1	0	0	2	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	8
																																				132

P_Cons

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	TOPLAM
Akhisar Belediyespor	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Antalyaspor	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beşiktaş	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bursaspor	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Çaykur Rizespor	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elazığspor	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eskişehirspor	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fenerbahçe	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Galatasaray	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gaziantepspor	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gençlerbirliği	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Karabükspor	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kasımpaşa	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kayserispor	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kayseri Erciyesspor	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sivasspor	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Torku Konyaspor	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trabzonspor	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
																																				0

P_Sameday

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	TOPLAM
3,7	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	14
3,8	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	10
3,18	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	10
7,8	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	10
7,18	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	10
8,18	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	14
																																			68

P_Comparable	P_Consecutive	P_Sameday	TOTAL PENALTIES
132	0	68	200

APPENDIX E

Penalty Results for GDSP-NLG Model Which is Using Data from TFF

P_Comp

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	TOPLAM
Akhisar Belediyespor	1	0	1	0	0	0	0	0	0	0	0	0	0	2	0	1	0	3	0	1	0	1	2	1	0	0	0	1	0	0	0	0	0	0	0	13
Antalyaspor	2	0	0	0	1	0	0	2	0	1	0	3	0	1	0	1	0	0	1	0	0	1	0	1	0	1	1	0	2	0	1	2	0	0	0	19
Beşiktaş	3	0	2	2	1	2	1	1	0	1	0	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	16
Bursaspor	4	0	0	1	0	1	2	0	0	1	2	0	0	0	0	0	1	1	0	0	1	2	2	0	0	0	1	0	2	2	0	0	0	1	0	20
Çaykur Rizespor	5	0	0	0	1	0	0	0	1	2	1	0	0	0	2	0	0	0	1	0	3	1	0	0	2	0	0	0	1	0	1	0	0	1	0	17
Elazığspor	6	0	1	1	1	0	0	0	1	0	0	1	0	1	0	0	0	1	1	2	1	2	1	1	1	0	1	2	1	2	2	0	0	0	0	24
Eskişehirspor	7	0	1	0	0	2	0	0	0	0	1	1	0	0	0	1	0	0	1	0	0	0	0	0	1	1	1	0	2	0	1	3	0	0	0	16
Fenerbahçe	8	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	2	0	2	0	1	0	2	0	2	2	1	2	0	0	1	0	19
Galatasaray	9	0	1	1	0	0	0	1	2	0	0	0	1	0	2	0	0	0	0	1	1	0	1	1	2	0	0	0	0	0	0	0	2	0	0	16
Gaziantepspor	10	0	3	0	0	0	0	0	0	0	0	2	1	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	1	0	1	1	0	0	0	13
Gençlerbirliği	11	0	0	0	1	0	0	0	0	0	0	1	2	0	1	2	1	1	0	0	0	1	0	0	0	1	0	1	2	1	0	0	0	0	0	15
Karabükspor	12	0	0	2	0	0	0	1	0	0	0	0	1	1	1	0	0	0	2	0	0	1	0	0	1	0	0	0	0	0	0	2	0	0	0	12
Kasımpaşa	13	0	0	0	0	1	0	0	0	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Kayserispor	14	0	2	0	0	1	3	2	1	2	1	1	0	0	0	0	1	0	0	2	0	0	0	1	1	1	3	0	3	0	0	0	0	0	2	27
Kayseri Erciyesspor	15	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	0	0	0	0	2	0	0	0	0	1	0	0	8
Sivasspor	16	0	2	1	1	0	0	0	0	0	0	2	0	0	0	2	1	1	0	0	1	1	1	0	1	0	0	0	0	0	0	1	0	0	2	17
Torku Konyaspor	17	0	0	1	0	0	0	0	0	0	0	0	1	2	2	0	0	0	0	1	1	0	2	0	0	0	0	0	0	0	0	1	0	0	0	11
Trabzonspor	18	0	1	3	1	0	2	0	0	1	2	0	2	0	1	0	1	0	2	0	1	0	0	0	1	1	1	0	0	2	0	0	1	1	1	25
																																				294

P_Cons

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	TOPLAM
Akhisar Belediyespor	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Antalyaspor	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beşiktaş	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bursaspor	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Çaykur Rizespor	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elazığspor	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eskişehirspor	7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Fenerbahçe	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Galatasaray	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gaziantepspor	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gençlerbirliği	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Karabükspor	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kasımpaşa	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kayserispor	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kayseri Erciyesspor	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sivasspor	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Torku Konyaspor	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trabzonspor	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
																																				2

P_Sameday

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	TOPLAM
3,7	1	0	0	1	0	0	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	1	1	1	0	11
3,8	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	4
3,18	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5
7,8	0	1	0	0	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	0	0	0	1	0	1	0	1	0	1	0	1	0	0	1	13
7,18	1	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0	11
8,18	0	0	0	0	0	1	1	1	0	0	1	1	0	0	0	1	1	0	0	1	0	0	0	1	1	0	0	0	1	0	0	1	0	0	12
																																			56

P_Comparable	P_Consecutive	P_Sameday	TOTAL PENALTIES
294	2	56	352

APPENDIX F

Penalty Results for GDSP-ALL Model

P_Comp

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	TOPLAM
Akhisar Belediyespor	1	0	0	0	0	0	2	0	0	0	0	0	0	1	2	1	0	2	0	5	4	4	0	0	0	1	0	0	0	0	0	0	1	0	0	23
Antalyaspor	2	0	1	0	1	0	2	0	0	0	0	0	1	0	3	0	3	0	3	3	0	0	1	0	0	0	0	4	1	0	4	1	1	0	0	29
Beşiktaş	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
Bursaspor	4	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	4	0	0	0	1	1	2	0	0	2	1	0	0	0	14
Çaykur Rizespor	5	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	6
Elazığspor	6	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	2	0	0	2	4	5	0	0	0	0	0	1	0	1	0	0	0	0	0	19
Eskişehirspor	7	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	3	0	0	3	0	0	0	0	0	0	0	2	0	0	5	0	0	2	0	18
Fenerbahçe	8	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Galatasaray	9	0	0	0	0	2	0	2	1	4	1	3	0	2	0	1	3	0	3	0	0	0	2	3	1	0	1	3	1	1	3	0	0	3	0	40
Gaziantepspor	10	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4
Gençlerbirliği	11	0	1	1	1	2	3	0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	1	0	1	0	0	0	0	0	0	16
Karabükspor	12	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	8
Kasımpaşa	13	0	1	0	0	0	0	5	0	0	0	3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	14
Kayserispor	14	0	0	0	0	0	1	0	0	0	1	1	1	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	1	12
Kayseri Erciyesspor	15	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5
Sivasspor	16	0	0	0	0	0	0	3	2	0	0	1	0	0	0	0	0	1	3	4	4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	19
Torku Konyaspor	17	0	0	0	1	0	4	0	0	0	0	2	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	1	0	0	12
Trabzonspor	18	0	3	3	1	3	0	4	0	3	0	4	0	4	0	3	0	0	0	0	0	0	4	3	1	1	0	0	0	0	0	0	0	0	1	38
																																				281

P_Cons

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	TOPLAM
Akhisar Belediyespor	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	1	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	9
Antalyaspor	2	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	2	0	2	2	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	10
Beşiktaş	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Bursaspor	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	2	2	0	0	0	0	0	1	0	0	1	0	0	0	0	10
Çaykur Rizespor	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Elazığspor	6	0	0	0	0	0	2	0	0	0	1	0	0	0	1	0	1	0	1	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	9
Eskişehirspor	7	0	0	0	0	0	2	0	0	0	1	0	0	0	2	0	2	0	1	1	1	1	0	0	0	0	0	1	0	0	3	0	0	1	0	16
Fenerbahçe	8	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Galatasaray	9	0	0	0	0	0	0	1	0	0	0	0	0	2	1	0	2	0	1	1	1	0	0	0	0	0	1	0	0	0	1	0	0	1	0	12
Gaziantepspor	10	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Gençlerbirliği	11	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Karabükspor	12	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Kasımpaşa	13	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Kayserispor	14	0	0	0	0	0	2	0	0	0	1	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Kayseri Erciyesspor	15	0	0	0	0	0	1	0	0	0	2	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Sivasspor	16	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	2	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Torku Konyaspor	17	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Trabzonspor	18	0	3	2	0	2	0	3	0	2	0	3	0	2	1	2	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	24
																																				133

P_Sameday

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	TOPLAM
3,7	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	1	11
3,8	0	0	0	0	1	0	0	0	1	0	1	1	1	1	0	0	0	0	0	1	0	1	1	0	0	0	0	1	1	1	1	0	1	0	14
3,18	1	1	1	1	1	0	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0		13
7,8	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	1	0	0	0	0	0	0	0	1	0	0		13
7,18	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	0	1	0	10
8,18	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	1		11
																																			72

P_Comparable	P_Consecutive	P_Sameday	TOTAL PENALTIES
281	133	72	486

APPENDIX G

Penalty Results for GDSP-ALL Model Which is Using Data from TFF

P_Comp

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	TOPLAM
Akhisar Belediyespor	1	0	1	0	0	0	2	0	0	0	0	0	0	2	2	1	0	3	0	5	2	4	2	1	0	0	0	1	0	0	0	0	0	0	0	26
Antalyaspor	2	0	0	0	1	0	2	0	0	1	0	0	0	1	2	1	3	0	4	3	0	0	0	1	0	1	1	4	2	0	5	2	0	0	0	34
Beşiktaş	3	0	2	2	1	0	0	1	0	1	0	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	13
Bursaspor	4	0	0	1	0	1	0	0	0	1	2	0	0	0	0	0	0	1	0	0	1	5	2	0	0	0	1	1	2	2	2	0	0	1	0	23
Çaykur Rizespor	5	0	0	0	1	0	0	1	1	2	0	0	0	0	0	0	0	0	1	0	3	1	0	0	2	0	0	0	1	0	1	0	0	1	0	15
Elazığspor	6	0	1	1	1	0	4	0	1	0	1	1	0	1	0	0	3	1	0	5	4	6	1	1	1	0	1	2	1	2	0	0	0	0	0	39
Eskişehirspor	7	0	1	0	0	2	4	0	0	0	0	1	0	0	0	1	4	0	0	2	0	0	0	0	1	1	1	3	2	0	5	3	0	4	0	35
Fenerbahçe	8	0	0	0	1	1	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	2	0	1	0	2	0	0	2	1	2	0	0	1	0	16
Galatasaray	9	0	1	1	0	2	0	5	2	2	0	3	1	4	0	2	2	0	4	0	0	0	1	5	2	0	1	3	0	0	4	0	2	3	0	50
Gaziantepspor	10	0	3	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	1	0	1	1	0	0	0	12
Gençlerbirliği	11	0	0	0	1	0	4	0	0	0	1	0	2	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	2	1	0	0	0	0	0	14
Karabükspor	12	0	0	2	0	0	0	1	0	0	4	0	1	1	0	0	4	0	2	0	0	1	0	0	1	0	0	0	0	0	0	2	0	0	0	19
Kasımpaşa	13	0	0	0	0	1	0	4	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Kayserispor	14	0	2	0	0	0	1	2	1	0	1	1	0	0	0	0	5	0	0	2	0	0	0	1	1	1	0	0	3	0	0	0	0	0	2	23
Kayseri Erciyesspor	15	0	0	0	0	0	0	1	0	0	2	0	0	0	0	1	0	1	0	1	0	0	1	0	0	0	0	2	0	0	0	0	1	0	0	10
Sivasspor	16	0	2	1	1	0	0	3	0	0	0	2	0	0	0	2	0	1	3	3	5	0	1	0	1	0	0	0	0	0	0	1	0	0	2	28
Torku Konyaspor	17	0	0	1	0	0	3	0	0	0	0	2	1	2	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	1	0	0	0	13
Trabzonspor	18	0	5	6	1	4	0	4	0	5	0	3	2	4	0	4	0	0	2	0	0	0	5	4	1	1	1	0	0	2	0	0	1	0	1	56
																																				433

P_Cons

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	TOPLAM
Akhisar Belediyespor	1	0	0	0	0	0	2	0	0	0	1	0	0	0	1	0	1	1	1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	11
Antalyaspor	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	2	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	7
Beşiktaş	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Bursaspor	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2	1	2	1	0	0	0	0	0	0	0	2	0	0	0	0	0	10
Çaykur Rizespor	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Elazığspor	6	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Eskişehirspor	7	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	2	0	2	2	2	0	0	0	0	0	0	0	0	0	1	0	0	1	0	13
Fenerbahçe	8	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Galatasaray	9	0	0	0	0	0	0	1	0	1	0	0	0	1	2	0	1	0	1	1	2	0	0	1	0	0	1	1	0	0	2	0	0	1	0	16
Gaziantepspor	10	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Gençlerbirliği	11	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Karabükspor	12	0	0	0	0	0	1	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Kasımpaşa	13	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Kayserispor	14	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Kayseri Erciyesspor	15	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Sivasspor	16	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Torku Konyaspor	17	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Trabzonspor	18	0	1	1	0	1	0	2	0	1	0	2	0	2	1	1	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	16
																																				118

P_Sameday

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	TOPLAM
3,7	1	0	0	1	0	0	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	1	1	1	0	11
3,8	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	4
3,18	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5
7,8	0	1	0	0	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	0	0	0	1	0	1	0	1	0	1	0	1	0	0	1	13
7,18	1	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0	11
8,18	0	0	0	0	0	1	1	1	0	0	1	1	0	0	0	1	1	0	0	1	0	0	0	1	1	0	0	0	1	0	0	1	0	0	12
																																			56

P_Comparable	P_Consecutive	P_Sameday	TOTAL PENALTIES
433	118	56	607

APPENDIX H

Fixed Match Days of Weeks

Assignment of match days from 1st week to 34th week

Fx TABLE

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	Akhisar Belediyespor	4	3	3	2	3	3	2	2	2	1	3	2	3	3	2	4	3	2	3	2	4	4	2	3	2	3	3	2	1	2	1	2	3	3
2	Antalyaspor	2	2	2	1	2	2	2	2	1	2	1	2	2	2	2	2	2	2	2	2	2	2	2	4	2	3	2	3	3	2	2	2	2	2
3	Beşiktaş	2	3	2	2	3	2	2	2	2	2	2	2	2	3	2	3	2	2	3	2	2	3	2	3	2	3	2	3	3	2	2	2	2	3
4	Bursaspor	2	1	2	2	3	3	2	4	2	3	2	3	1	1	3	2	2	3	2	2	2	3	2	3	4	3	2	4	2	4	3	3	3	4
5	Çaykur Rizespor	3	3	2	2	3	1	2	2	3	1	2	1	3	3	2	3	1	1	3	1	3	3	1	4	2	3	3	3	3	2	2	2	2	2
6	Elazığspor	4	3	3	3	2	2	1	2	3	3	3	3	1	2	2	3	1	2	3	3	3	2	3	3	3	2	3	2	2	4	2	2	2	2
7	Eskişehirspor	2	2	2	3	2	2	2	2	3	2	3	3	3	2	3	2	3	3	2	3	2	2	2	3	3	3	3	2	2	3	3	3	3	2
8	Fenerbahçe	3	2	3	3	2	2	3	3	2	3	2	2	2	3	2	3	3	3	2	3	2	2	3	2	2	2	2	3	3	2	2	2	3	3
9	Galatasaray	2	1	2	1	3	1	2	2	2	2	2	2	2	2	3	2	2	2	2	3	2	3	1	3	3	4	2	3	3	3	2	3	2	1
10	Gaziantepspor	2	2	2	2	3	3	3	3	2	3	3	3	2	2	3	2	2	2	2	2	3	4	2	2	2	2	1	2	2	3	3	3	3	4
11	Gençlerbirliği	3	3	3	3	2	2	3	3	3	2	3	3	2	1	3	2	2	1	3	2	3	2	3	2	3	2	3	2	2	3	3	3	2	3
12	Karabükspor	3	3	3	2	4	3	2	2	1	2	2	2	3	3	1	3	3	3	3	2	3	3	2	3	3	3	2	3	1	3	3	1	3	2
13	Kasımpaşa	3	2	4	3	2	2	1	3	3	3	3	3	2	2	2	3	3	3	1	3	2	2	2	3	3	2	3	2	2	3	2	2	2	3
14	Kayserispor	3	2	3	3	3	3	3	4	2	2	2	1	3	3	3	3	3	3	1	3	3	3	3	3	2	4	4	2	3	3	2	3	3	4	3
15	Kayseri Erciyesspor	2	3	2	2	4	3	3	3	3	3	3	3	3	2	3	2	2	2	3	1	4	3	3	2	2	2	3	2	2	3	3	3	3	1
16	Sivasspor	3	2	3	3	2	2	3	3	3	3	2	2	2	3	2	4	3	3	2	3	2	2	3	2	3	2	1	4	3	2	2	2	3	2
17	Torku Konyaspor	3	2	4	3	2	3	3	3	2	2	1	2	3	3	1	3	3	3	2	3	3	2	3	2	2	3	2	3	3	2	1	1	4	2
18	Trabzonspor	2	3	3	2	3	3	3	3	3	3	3	3	3	2	3	2	2	2	3	2	3	3	3	2	3	2	3	2	2	3	3	3	2	2

The last update (the fixed match days of weeks are shown below from 1st week to 30th week)

Fx TABLE

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	Akhisar Belediyespor	4	3	3	3	1	3	2	2	3	3	2	3	3	3	3	2	1	3	3	2	2	3	3	2	3	3	3	2	4	3	3	2	2	1
2	Antalyaspor	2	2	2	2	2	2	2	2	3	4	4	2	2	2	1	4	3	2	2	3	3	2	3	2	3	3	2	3	3	2	2	1	3	3
3	Beşiktaş	2	3	2	3	3	2	2	2	3	3	3	2	2	2	3	3	3	2	2	3	2	2	3	2	3	3	2	3	3	2	2	2	2	2
4	Bursaspor	2	1	2	3	3	3	3	3	1	2	1	3	1	4	3	3	2	3	2	3	2	3	3	3	2	3	2	4	2	4	2	3	3	3
5	Çaykur Rizespor	3	3	2	3	3	1	2	2	2	3	3	2	4	2	2	2	3	2	2	3	2	3	4	2	3	3	3	3	3	2	3	2	1	4
6	Elazığspor	4	3	3	2	3	2	4	2	2	2	2	3	1	2	1	3	3	3	3	2	3	2	2	2	3	2	3	2	2	4	2	1	2	4
7	Eskişehirspor	2	2	2	2	2	2	2	2	2	3	2	3	3	3	2	3	2	3	3	2	3	2	3	2	3	3	3	2	2	3	3	3	3	2
8	Fenerbahçe	3	2	3	2	3	3	3	3	2	2	3	2	2	2	3	2	2	3	3	3	3	2	2	3	2	2	2	3	3	2	3	2	2	3
9	Galatasaray	2	1	2	2	3	1	2	2	3	2	3	2	2	2	3	3	3	3	2	2	3	2	4	2	1	2	1	3	2	2	2	2	3	2
10	Gaziantepspor	2	2	2	3	1	4	2	3	2	3	2	3	3	3	4	3	2	3	2	3	2	3	3	3	2	2	2	2	2	3	3	3	3	3
11	Gençlerbirliği	3	3	3	4	2	3	3	4	2	3	2	4	3	4	3	4	3	2	3	2	4	4	2	4	3	2	3	2	3	3	2	2	3	2
12	Karabükspor	3	3	3	3	2	4	3	2	3	3	3	3	3	3	2	2	2	4	3	2	2	3	3	3	1	3	2	3	4	3	4	3	2	3
13	Kasımpaşa	3	2	4	2	4	2	4	4	3	2	2	3	2	2	3	2	1	4	3	4	3	2	3	2	3	2	3	2	2	2	2	2	1	1
14	Kayserispor	3	2	3	4	3	3	2	3	3	4	3	2	3	3	2	2	2	2	3	2	4	3	2	3	2	2	2	3	3	3	4	3	2	3
15	Kayseri Erciyesspor	2	3	2	3	2	3	3	3	2	2	2	4	3	3	4	3	3	2	2	3	2	3	2	3	2	1	3	2	3	3	3	3	3	2
16	Sivasspor	3	2	3	2	4	2	3	3	2	3	1	2	2	2	2	2	2	4	3	3	2	2	4	2	1	2	4	2	2	2	2	2	2	3
17	Torku Konyaspor	3	2	4	2	2	3	3	3	1	2	4	2	4	3	2	2	2	3	4	4	3	4	2	3	2	3	1	3	3	2	3	3	2	2
18	Trabzonspor	2	3	3	3	3	3	3	3	3	2	2	3	3	3	3	3	3	2	2	2	2	3	2	3	2	2	3	2	2	3	3	3	3	3

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Curriculum Vitae

Duygu Bilgesu was born on 1 March 1988, in İstanbul. She received her BS degree in Industrial Engineering from Işık University in 2013. She completed her M.S. degree in 2016 in Operations Research from Işık University. The first qualified Project Engineer employed by Teknopalas her functions included all office management, to manage the projects. The main business area of the company is RFID system solutions & projects. She analyzes the project process and all the systems about softwares of the projects and implementation of various project activities. Her research interests include operations research, scheduling and mathematical modelling.