



НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ
УНИВЕРСИТЕТ

Faculty of Computer Science

SCHEDULING THE RUSSIAN PREMIER LEAGUE: ILP-BASED APPROACH

Sumin Daniil

Mentor: Makarov Ilya

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PROBLEM DESCRIPTION

1

16 teams

2


































30 slots

3

Double round-robin format

4

A lot of constraints from organizers

☆  RUSSIA: Premier League					
Round 24					
☆ 03.04. 14:00	R. Volgograd		-		Lokomotiv Moscow
☆ 03.04. 16:30	Krasnodar		-		Akhmat Grozny
☆ 03.04. 16:30	Rubin Kazan		-		Sochi
☆ 03.04. 19:00	Dynamo Moscow		-		Ufa
☆ 04.04. 14:00	Ural		-		Arsenal Tula
☆ 04.04. 16:30	Tambov		-		CSKA Moscow
☆ 04.04. 19:00	FK Rostov		-		Spartak Moscow
☆ 05.04. 19:00	Zenit		-		Khimki
Round 25					
10.04. 14:00	Khimki		-		Tambov
10.04. 16:30	Ufa		-		Akhmat Grozny
10.04. 19:00	FK Rostov		-		Rubin Kazan
11.04. 14:00	Arsenal Tula		-		Krasnodar
11.04. 16:30	Dynamo Moscow		-		Ural
11.04. 16:30	Sochi		-		Zenit
11.04. 19:00	Lokomotiv Moscow		-		Spartak Moscow
12.04. 19:00	CSKA Moscow		-		R. Volgograd



OBJECTIVES

1

Develop a tool that allows you to create a RPL schedule for the season

2

Implement the flexible addition of new constraints

3

Create a calendar for the 20/21 season and compare it with the actual one

4

Suggest ideas for new constraints for the winter season

SOLUTION APPROACH

Integer linear programming

Decision variables

$z[s, t_1, t_2]$ – binary

Team t_1 plays at home against team t_2 in the slot s

Constraints

«Hard»

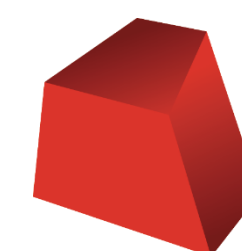
«Soft»

Objective function

f = Sum of penalties for soft constraints violations

$$f \xrightarrow{\text{w.r.t. } Z} \min$$

Technology stack



GUROBI
OPTIMIZATION



CONSTRAINTS

«Hard» Constraints

1. Double Round-Robin Constraints

2. Home-Away Constraints

3. Top Teams Constraints

«Soft» Constraints

1. Without top opponents before euro slots for euro teams

2. Without away breaks



TEAMS AND SLOTS CHARACTERISTICS

Teams					
Top					
Zenit	Krasnodar	CSKA	Lokomotiv	Spartak	
North					
	Arsenal	Rubin	Ufa	Ural	
South					
	Sochi	Krasnodar	Zenit*	Akhmat	
Euro cups					
Zenit	Krasnodar	CSKA	Lokomotiv	Dinamo	Rostov

Slots									
Winter (Dec and Feb)									
17			18		19		20		
Before euro cups									
7	8	9	11	12	13	15	16	17	

* Stadium with roof

DOUBLE ROUND-ROBIN CONSTRAINTS

S – set of slots

T – set of teams

P_1 – set of 1th phase slots

P_2 – set of 2nd phase slots

1	1 game per slot for each team	$\sum_{t_2 \in T: t_2 \neq t_1} (z[s, t_1, t_2] + z[s, t_2, t_1]) = 1; \quad s \in S, t_1 \in T$
2	1 game between any two teams in the first phase	$\sum_{s \in P_1} (z[s, t_1, t_2] + z[s, t_2, t_1]) = 1; \quad t_1 \in T, t_2 \in T, t_1 > t_2$
3	1 game between any two teams in the second phase	$\sum_{s \in P_2} (z[s, t_1, t_2] + z[s, t_2, t_1]) = 1; \quad t_1 \in T, t_2 \in T, t_1 > t_2$
4	1 home and 1 away game between any two teams	$\sum_{s \in S} (z[s, t_1, t_2]) = 1; \quad t_1 \in T, t_2 \in T, t_1 \neq t_2$

HOME-AWAY CONSTRAINTS

T_s – set of South teams
 T_N – set of North teams
 S_w – set of winter slots

1	Without 3 consecutive home games for each team*	$\sum_{t_2 \in T: t_1 \neq t_2} \sum_{p=s}^{s+2} z[p, t_1, t_2] \leq 2; \quad s \in S: s+2 \in S, t_1 \in T \setminus T_s$
2	Without 3 consecutive away games for each team*	$\sum_{t_2 \in T: t_1 \neq t_2} \sum_{p=s}^{s+2} z[p, t_2, t_1] \leq 2; \quad s \in S: s+2 \in S, t_1 \in T \setminus T_N$
3	South teams play only home in winter slots	$\sum_{s \in S_w} \sum_{t_2 \in T: t_1 \neq t_2} z[s, t_1, t_2] = 4; \quad t_1 \in T_s$
4	North teams play only away in winter slots	$\sum_{s \in S_w} \sum_{t_2 \in T: t_1 \neq t_2} z[s, t_1, t_2] = 0; \quad t_1 \in T_N$

* Not for south/north teams in winter period

TOP TEAMS CONSTRAINTS

T_A – set of Top teams

1

Without top games in the first and last slots

$$\sum_{t_2 \in T_A: t_1 \neq t_2} (z[1, t_1, t_2] + z[30, t_1, t_2]) = 0; \quad t_1 \in T_A$$

2

No more than 1 top game in other slots

$$\sum_{t_2 \in T_A: t_1 \neq t_2} (z[s, t_1, t_2]) \leq 1; \quad t_1 \in T_A, s \in S \setminus \{1; 30\}$$

3

No more than 3 top opponents in any 5 consecutive games

$$\sum_{t_2 \in T_A: t_1 \neq t_2} \sum_{p=s}^{s+4} (z[p, t_1, t_2] + z[p, t_2, t_1]) \leq 3; \quad s \in S: s+4 \in S, t_1 \in T$$

SOFT CONSTRAINTS

S_E – set of Euro slots

T_E – set of Euro teams

$b[s, t]$ – binary variable, team t has away break in slot s

1

Without top opponents before euro slots for “euro teams”

$$\sum_{t_1 \in T_E} \sum_{t_2 \in T_A: t_1 \neq t_2} \sum_{s \in S_E} (z[s, t_1, t_2] + z[s, t_2, t_1]) = 0; \quad t_1 \in T_s$$

2

Without away breaks

$$\sum_{t_1 \in T} \sum_{s \in S \setminus \{1\}} b[s, t] = 0$$

3

Away breaks linearization

$$\sum_{t_2 \in T: t_1 \neq t_2} (z[s-1, t_2, t_1] + z[s, t_2, t_1]) \leq 1 + b[s, t_1]; \quad t_1 \in T, s \in S \setminus \{1\}$$

INPUT DATA FORMAT

RobinX: an XML-driven classification for round-robin sports timetabling (David Van Bulck, Dries Goossens, Jörn Schönberger, Mario Guajardoc)

```
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Winter slots constraints for North
and South teams

```
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<CA4 max="1" min="0" mode1="H" mode2="GLOBAL" penalty="1" slots="10" teams1="4;5;6;11;16" teams2="4;5;6;11;16" type="HARD"/>
```

Top games constraints



RESULTS

Comparison with the actual RPL calendar for the 20/21 season

IP model 1 – 30 minutes
IP model 2 – 20 hours

Constraint	Type	Number of violations		
		Actual calendar	IP model 1	IP model 2
3 consecutive home (away) games	Hard	8	0	0
South teams play only home in winter slots	Hard	1	0	0
2 away games in a row	Soft	77	71	49
Top opponents before euro slots for “euro teams”	Soft	4	0	0
Others	Hard	0	0	0



EXAMPLES

Spartak 20/21 season schedule

Actual schedule					IP Model 2				
Slot	Opponent	Status	Top opponent	Break	Slot	Opponent	Status	Top opponent	Break
1	Sochi	H			1	Rostov	A		
2	Akhmat	H		1	2	Rubin	H		
3	Ufa	A			3	Ural	A		
4	Lokomotiv	H	1		4	Ufa	H		
5	Rotor	A			5	Dinamo	A		
6	Arsenal	H			6	Khimki	H		
7	CSKA	A	1		7	Arsenal	A		
8	Rubin	A		1	8	CSKA	H	1	
9	Tambov	A		1	9	Zenit	A	1	
10	Zenit	H	1		10	Lokomotiv	H	1	
11	Khimki	A			11	Tambov	A		
12	Krasnodar	A	1	1	12	Akhmat	H		
13	Rostov	H			13	Sochi	A		
14	Ural	A			14	Krasnodar	H	1	
15	Dinamo	H			15	Rotor	A		
16	Rotor	H		1	16	Sochi	H		
17	Tambov	H		1	17	Akhmat	A		
18	Sochi	A			18	Tambov	H		
19	Zenit	A	1	1	19	Krasnodar	A	1	
20	Rubin	H			20	Ural	H		
21	Krasnodar	H	1	1	21	Rubin	A		
22	Dinamo	A			22	Zenit	H	1	
23	Ural	H			23	Khimki	A		
24	Rostov	A			24	Rotor	H		
25	Lokomotiv	A	1	1	25	CSKA	A	1	
26	Ufa	H			26	Rostov	H		
27	CSKA	H	1	1	27	Lokomotiv	A	1	
28	Arsenal	A			28	Arsenal	H		
29	Khimki	H			29	Ufa	A		
30	Akhmat	A			30	Dinamo	H		



EXAMPLES

Ufa 20/21 season schedule

Actual schedule					IP Model 2				
Slot	Opponent	Status	Top opponent	Break	Slot	Opponent	Status	Top opponent	Break
1	Krasnodar	H	1		1	Tambov	H		
2	Arsenal	A			2	Khimki	A		
3	Spartak	H	1		3	Sochi	H		
4	Rostov	H		1	4	Spartak	A	1	
5	Rubin	A			5	Rotor	H		
6	Dinamo	H			6	Akhmat	H		1
7	Tambov	A			7	Lokomotiv	A	1	
8	CSKA	H	1		8	Rubin	H		
9	Zenit	A	1		9	Rostov	H		1
10	Rotor	H			10	Ural	A		
11	Lokomotiv	A	1		11	CSKA	A	1	1
12	Akhmat	A		1	12	Dinamo	H		
13	Ural	H			13	Krasnodar	A	1	
14	Sochi	A			14	Arsenal	H		
15	Khimki	H			15	Zenit	A	1	
16	Tambov	H		1	16	CSKA	H	1	
17	Rostov	A			17	Sochi	A		
18	Rotor	A		1	18	Dinamo	A		1
19	Krasnodar	A	1	1	19	Tambov	A		1
20	Khimki	A		1	20	Rostov	A		1
21	Ural	A		1	21	Zenit	H	1	
22	Rubin	H			22	Lokomotiv	H	1	1
23	Lokomotiv	H	1	1	23	Rotor	A		
24	Dinamo	A			24	Khimki	H		
25	Akhmat	H			25	Krasnodar	H	1	1
26	Spartak	A	1		26	Arsenal	A		
27	Sochi	H			27	Ural	H		
28	CSKA	A	1		28	Rubin	A		
29	Zenit	H	1		29	Spartak	H	1	
30	Arsenal	H		1	30	Akhmat	A		



POTENTIAL IMPROVEMENTS

1

Decrease the number of the breaks

2

Expansion of the number of winter slots

3

More flexible approach for south and north teams' classification



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