



# Seattle Seahawks Scheduling Problem

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# Agenda



INTRO



PROBLEM  
DESCRIPTION



NUMERICAL  
IMPLEMENTATION

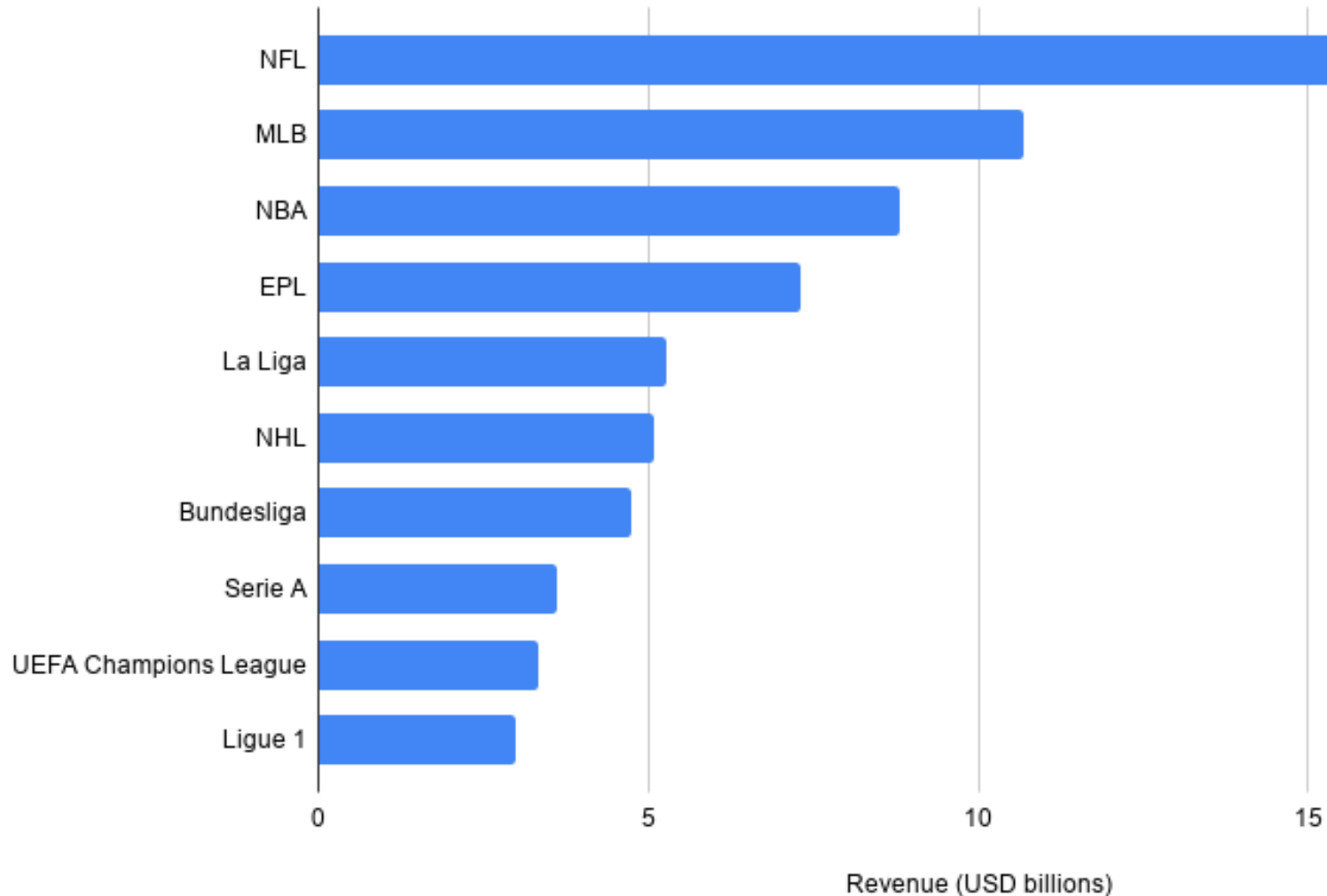


PROBLEM  
EXTENSION



CONCLUSION

## Largest Sports League by Revenue



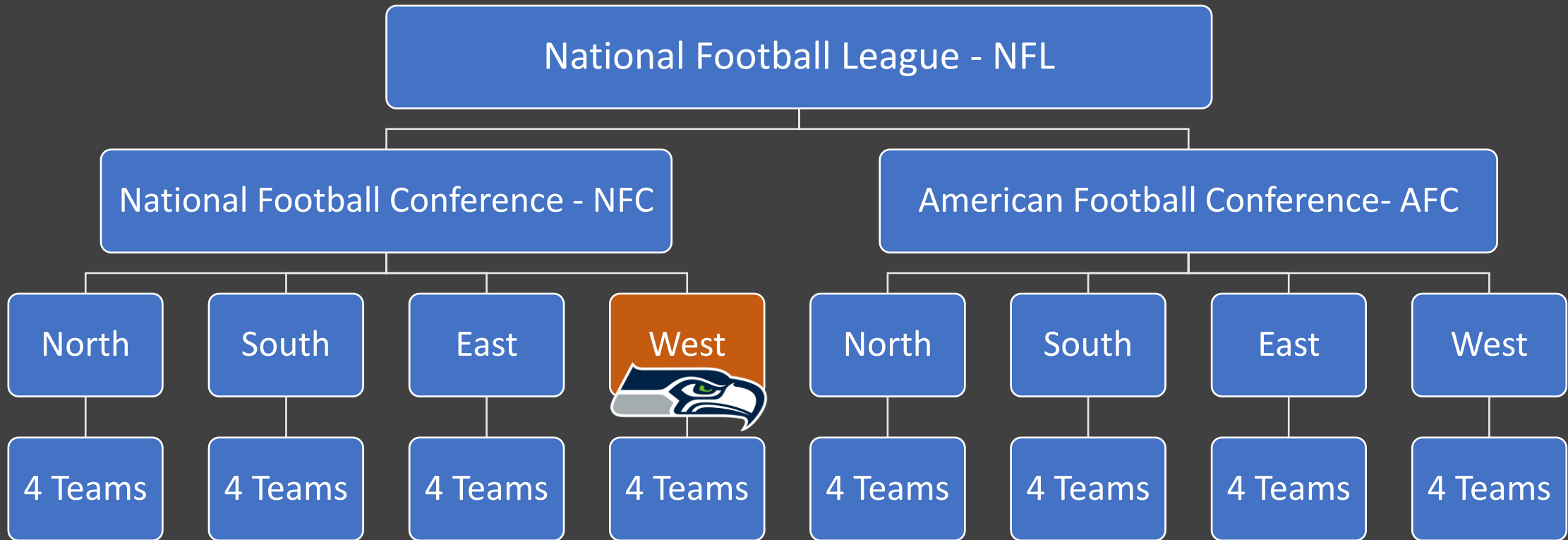
**\$13 billion**

NFL revenue in 2020

**7.3 million**

mean game viewership in 2021

# National Football League






# Scope

- NFL uses integer programming to create the schedule since 2013
- This is considered an incredibly complex and scrutinized problem
- Challenges:
  - 824 trillion game combinations
  - Objective function variations:
    - Maximize game value (expected revenue)
    - Maximize viewership
    - Maximize fairness
    - Minimize travel costs
    - And more...
  - Thousands of constraints (and increasing)
    - Stadium availability
    - Travel considerations
    - Competitive equity
    - Internal rules
- Takes the NFL 12 weeks each year to create the schedule
- **Goal: determine season schedule (game days, opponents, bye-week) for the Seattle Seahawks.**



Week / Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Team
1	?	?	?	?	?	?	?	?
2	?	?	?	?	?	?	?	?
3	?	?	?	?	?	?	?	?
4	?	?	?	?	?	?	?	?
5	?	?	?	?	?	?	?	?
6	?	?	?	?	?	?	?	?
7	?	?	?	?	?	?	?	?
8	?	?	?	?	?	?	?	?
9	?	?	?	?	?	?	?	?
10	?	?	?	?	?	?	?	?
11	?	?	?	?	?	?	?	?
12	?	?	?	?	?	?	?	?
13	?	?	?	?	?	?	?	?
14	?	?	?	?	?	?	?	?
15	?	?	?	?	?	?	?	?
16	?	?	?	?	?	?	?	?
17	?	?	?	?	?	?	?	?
18	?	?	?	?	?	?	?	?





# Problem Formulation

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# Decision Variables

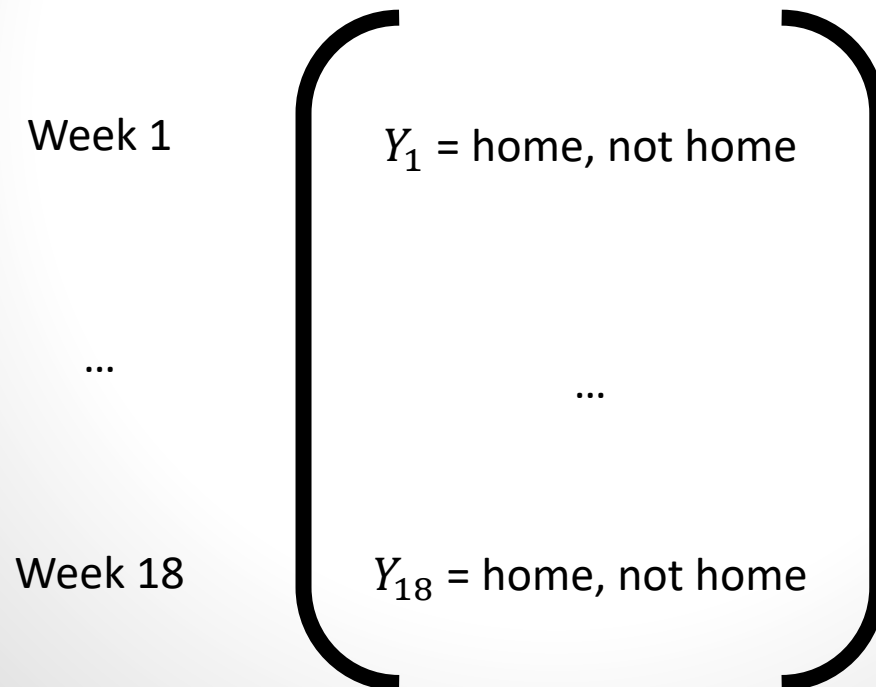
- $X_{ij}$  (binary) game **played/not played** on week  $i$  (from 1-18) on day  $j$  (from Monday to Sunday)

	Monday	...	Sunday
Week 1	$X_{1,Monday}$	...	$X_{1,Sunday}$
...	...	...	...
Week 18	$X_{18,Monday}$	...	$X_{18,Sunday}$



# Decision Variables

- $Y_i$  (binary) game played at **home or not at home** (need to account for the bye-week) on week  $i$  (from 1-18)



# Decision Variables

- $Z_{ij}$  (binary) game **played/not played** on week  $i$  (from 1-18) against team  $j$  (from 1-31)

	Arizona Cardinals	...	Washington Football Team
Week 1	$Z_{1,Arizona Cardinals}$	...	$Z_{1,Washington Football Team}$
...	...	...	...
Week 18	$Z_{18,Arizona Cardinals}$	...	$Z_{18,Washington Football Team}$

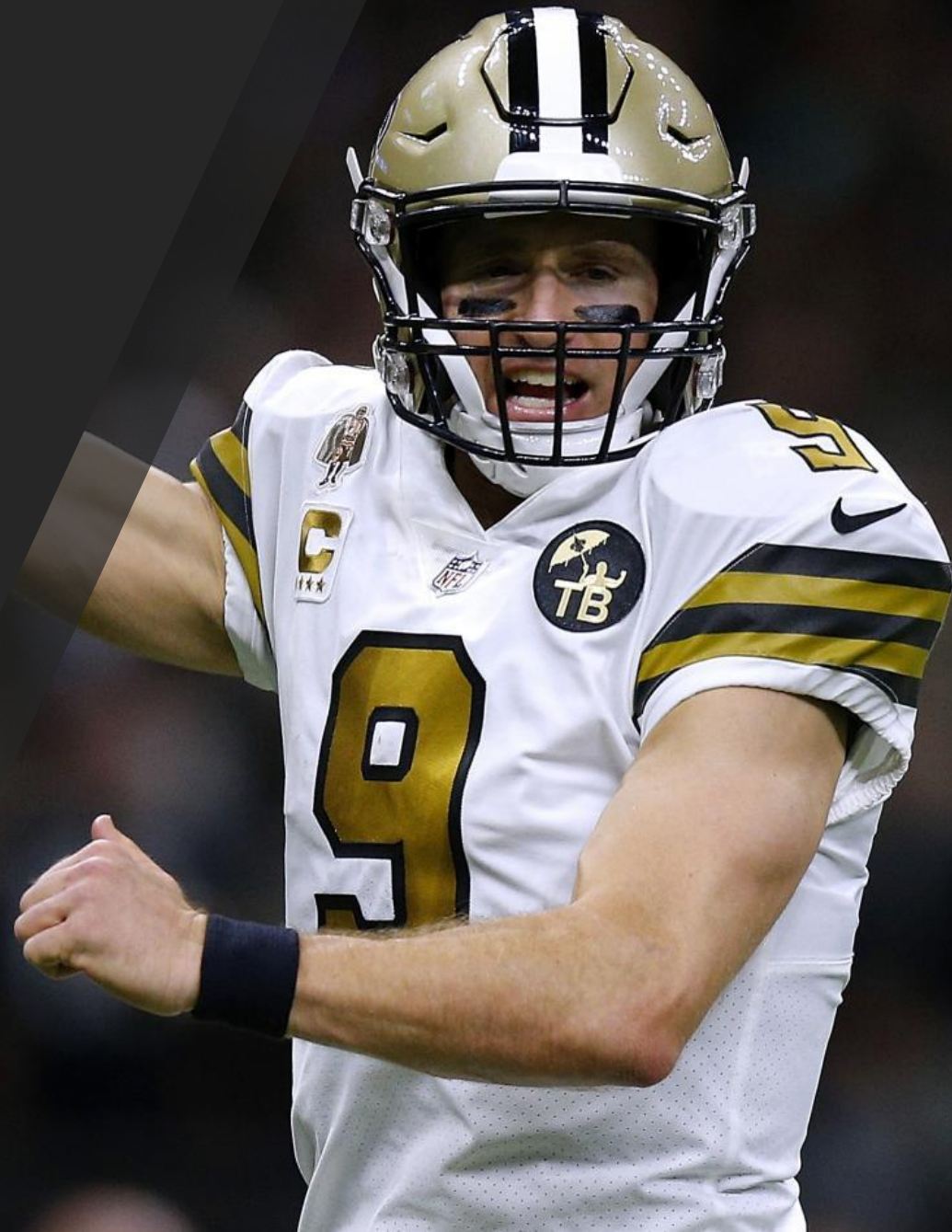
# Decision Variables

- $N_i$  (integer) total number of games played in the NFC division  $i$  (North, East, South)
- $A_i$  (integer) total number of games played in the AFC division  $i$  (North, East, South, West)
- $T_i$  (binary) dummy variable for  $N_i$  games (1-3)
- $S_i$  (binary) dummy variable for  $A_i$  games (1-4)

# Objective Function

- Objective - Maximize the number of games in a regular season to generate the schedule

$$\sum x_{ij}$$







# Constraints – Number of games

- Can only play **at most 1 game a week**, both  $X_{ij}$  and  $Z_{ij}$  must reflect this:

$$\sum X_{ij} \leq 1 \text{ \& } \sum Z_{ij} \leq 1$$

- Must **have 1 week off** for the bye week between the 6th week and 14th week inclusively. This means that the total number of games that can be played between weeks 6 and 14 must be 8:

$$\sum X_{ij} = 8, \text{ where } i \text{ is between 6 and 14 inclusively}$$

- Must **have 17 Games in a season**, both  $X_{ij}$  and  $Z_{ij}$  must reflect this:

$$\sum X_{ij} = 17 \text{ \& } \sum Z_{ij} = 17$$

- If there is a game **during the week of  $X_{ij}$** , then there must be a **game during  $Z_{ij}$** . This is to account for the bye-week:

$$\sum Z_{ij} = \sum X_{ij}$$

# Constraints – Days of the week

- Games are **not played on Tuesdays, Wednesdays, and Fridays**:

$$\sum X_{ij} = 0, \text{ for each } j \text{ where it is Tues, Wed, and Fri}$$

- Games are **not played on Saturday during weeks 1-13, and 17**:

$$X_{i, \text{Saturday}} = 0, \text{ for each } i \text{ weeks } 1 - 13 \text{ and } 17$$

- If the team **plays on Sunday on week i, they cannot play on Monday week i+1**:

$$X_{i, \text{Sunday}} + X_{i+1, \text{Monday}} \leq 1, \text{ where } i \text{ runs from } 2 \text{ to } 18$$



# Constraints – Days of the week (Cont.)

- Must have 1 Monday and 1 Thursday in the schedule:

$$\sum X_{i,Monday} = 1 \text{ \& } \sum X_{i,Thursday} = 1$$

- At most one Saturday in the schedule:

$$\sum X_{i,Saturday} \leq 1$$

- If the team plays on Saturday on week  $i$ , they cannot play on Monday week  $i+1$  (avoid games being too close):

$$X_{i,Saturday} + X_{i+1,Monday} \leq 1, \text{ where } i \text{ runs from 2 to 18}$$



# Constraints – Home/Away Games

- There is a total of 8 home games in a regular season:

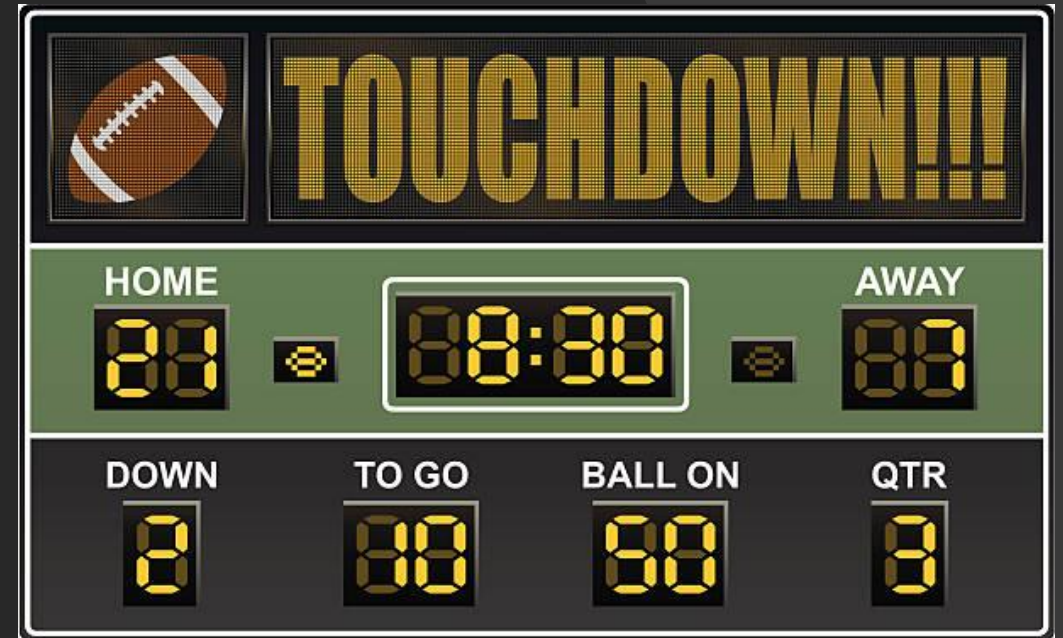
$$\sum Y_i = 8$$

- There cannot be more than 2 back-to-back away/road games in the season. This means that within 3 weeks, the sum of  $y$  should be at minimum equal to 1 home game:

$$\sum Y_i + Y_{i+1} + Y_{i+2} \geq 1, \text{ where } i \text{ ranges from weeks } 1 - 16$$

- If there is a game on  $X_{ij}$ , then the game is either home or away.  
This is to account for the bye-week:

$$Y_i \leq \sum X_{ij} \text{ for each week } i$$





# Constraints – Divisions and Conferences

- Must have 2 games per team in the same division (NFC West):



$$\sum Z_{i, \text{Arizona Cardinals}} = 2$$



$$\sum Z_{i, \text{LA Rams}} = 2$$



$$\sum Z_{i, \text{San Francisco 49ers}} = 2$$

# Constraints – Divisions and Conferences

- Must have 6 games against the 3 remaining divisions in their conference. Can't play the same team more than once. 4 must be with 1 division. 2 must be against a team from each of the 2 other divisions:



$$N_{North} + N_{East} + N_{South} = 6$$

$$\sum Z_{ij} = N_{North}, \text{ where the } j \text{ is the}$$

*North division teams*

$$\sum Z_{ij} = N_{East}, \text{ where the } j \text{ is the}$$

*East division teams*

$$\sum Z_{ij} = N_{South}, \text{ where } j \text{ is the}$$

*South division teams*

# Constraints – Divisions and Conferences

- Must have 6 games against the 3 remaining divisions in their conference. **Can't play the same team more than once.** 4 must be with 1 division. 2 must be against a team from each of the 2 other divisions:



$\sum Z_{ij} \leq 1$ , where  $j$  is the North, South, and East division teams for each  $i$  week 1 – 18

# Constraints – Divisions and Conferences

- Must have 6 games against the 3 remaining divisions in their conference. Can't play the same team more than once. **4 must be with 1 division. 2 must be against a team from each of the 2 other divisions:**



1  
1  
4



1  
4  
1



4  
1  
1



# Constraints – Divisions and Conferences

- Must have 6 games against the 3 remaining divisions in their conference. Can't play the same team more than once. 4 must be with 1 division. 2 must be against a team from each of the 2 other divisions:

$$N_{North} = 1 * t_1 + 1 * t_2 + 4 * t_3$$

$$N_{East} = 1 * t_1 + 4 * t_2 + 1 * t_3$$

“N possible values” method

$$N_{South} = 4 * t_1 + 1 * t_2 + 1 * t_3$$

$$t_1 + t_2 + t_3 = 1$$

# Constraints – Divisions and Conferences

- Must have 5 games against divisions in the other conference (AFC).  
Cannot play the same team more than once. 4 games must be with 1 division and 1 game from any other division:



$$A_{North} + A_{East} + A_{South} + A_{West} = 5$$

$$\sum Z_{ij} = A_{North}, \text{ where } j$$

*is the AFC North teams*

$$\sum Z_{ij} = A_{East}, \text{ where } j$$

*is the AFC East teams*

$$\sum Z_{ij} = A_{South}, \text{ where } j$$

*is the AFC South teams*

$$\sum Z_{ij} = A_{West}, \text{ where } j$$

*is the AFC West teams*

# Constraints – Divisions and Conferences

- Must have 5 games against divisions in the other conference (AFC).  
**Cannot play the same team more than once.** 4 games must be with 1 division and 1 game from any other division:



$$\sum Z_{ij} \leq 1, \text{ where } j \text{ is all the teams in the AFC for each } i \text{ week } 1 - 18$$

# Constraints – Divisions and Conferences

- Must have 5 games against divisions in the other conference (AFC). Cannot play the same team more than once. **4 games must be with 1 division and 1 game from any other division:**



Many combinations with 4 divisions and 4 possible outcomes for each division



# Constraints – Divisions and Conferences

- Must have 5 games against divisions in the other conference (AFC). Cannot play the same team more than once. 4 games must be with 1 division and 1 game from any other division:

$$A_{North} \geq 4 - M * S_1$$

$$A_{East} \geq 4 - M * S_2$$

$$A_{South} \geq 4 - M * S_3$$

$$A_{West} \geq 4 - M * S_4$$

$$S_1 + S_2 + S_3 + S_4 = 3$$

“Big M” method to determine which division will get the 4 games

# Numerical Implementation and Results

Data we are using is from NFL Website

To formulate the model, we have declared the variables and stored the following details –

- Created lists to store the names of 31 teams excluding Seattle Seahawks
- We have two conferences – AFC, NFC
- Each conference has 4 divisions – AFC North, AFC South, AFC West, AFC East and NFC North, NFC South, NFC East and **NFC West**
- Each division has 4 teams except for NFC West which has only 3 as Seattle Seahawks is part of it
- Day of the week – Monday, Tuesday, Wednesday... Sunday
- Total game weeks – 18
- Total games – 17

```
# list of teams in the NFL (without Seattle)
teams = ["Arizona Cardinals", "Atlanta Falcons", "Baltimore Ravens",
        "Buffalo Bills", "Carolina Panthers", "Chicago Bears",
        "Cincinnati Bengals", "Cleveland Browns", "Dallas Cowboys",
        "Denver Broncos", "Detroit Lions", "Green Bay Packers",
        "Houston Texans", "Indianapolis Colts", "Jacksonville Jaguars",
        "Kansas City Chiefs", "Las Vegas Raiders", "Los Angeles Chargers",
        "Los Angeles Rams", "Miami Dolphins", "Minnesota Vikings",
        "New England Patriots", "New Orleans Saints", "New York Giants",
        "New York Jets", "Philadelphia Eagles", "Pittsburgh Steelers",
        "San Francisco 49ers", "Tampa Bay Buccaneers", "Tennessee Titans",
        "Washington Football Team"]

# Teams in each division based off of
# the team name's index from the "teams" list
AFC_East = [3, 19, 21, 24]
AFC_North = [2, 6, 7, 26]
AFC_South = [12, 13, 14, 29]
AFC_West = [9, 15, 16, 17]
NFC_East = [8, 23, 25, 30]
NFC_North = [5, 10, 11, 20]
NFC_South = [1, 4, 22, 28]
NFC_West = [0, 18, 27] # seattle is in this division
NFC_all = [1, 4, 5, 8, 10, 11, 20, 22, 23, 25, 28, 30]

# list of all teams in the NFC besides teams in the NFC West
days_of_week = ["Monday", "Tuesday", "Wednesday",
                "Thursday", "Friday", "Saturday", "Sunday"]

number_days = len(days_of_week)
number_teams = len(teams)
number_weeks = 18
number_games = 17
```

# Model Results

Week / Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Team
1							Home Game	Los Angeles Rams
2							Away Game	Arizona Cardinals
3				Away Game				Tampa Bay Buccaneers
4	Home Game							Cincinnati Bengals
5							Away Game	Los Angeles Rams
6							Home Game	Green Bay Packers
7							Home Game	Kansas City Chiefs
8	B	Y	E		W	E	E	K
9							Away Game	Las Vegas Raiders
10							Home Game	Atlanta Falcons
11							Home Game	San Francisco 49ers
12							Away Game	Washington Football Team
13							Home Game	San Francisco 49ers
14							Away Game	Arizona Cardinals
15							Away Game	New Orleans Saints
16							Home Game	Los Angeles Chargers
17							Away Game	Carolina Panthers
18							Away Game	Denver Broncos

- As mentioned before, there are multiple ideas out there of what to use as an objective function for this type of problem:
  - Objective function variations:
    - Maximize game value (expected revenue)
    - Maximize viewership
    - Maximize fairness
    - Minimize travel costs
    - And more...
- Of the \$13 billion in annual revenue, broadcasting contracts make up over 50% of all revenue
- Therefore, league earnings should vary based on TV viewership



**Extension: maximize game value, using past viewership as proxy.**

$$\text{Objective} = \sum X_{ij} \text{viewership}_{ij}$$



# Data Gathering

- We looked at past viewership for games on each day of the week in each week of the season, aggregated for all teams.
- Sunday games are typically the most viewed, with the exception of holiday games
- Tradeoff: Seahawks specific data vs. complete data
- Future extensions: account for excluded variables

Week 17									
WINDOW	GAME	NET	RTG.	+/-	VWRS.	+/-	A18-49	A18-34	A25-54
Late DH	CHI-GB (76%)	FOX	12.25	+6%	23.01M	+10%	6.0	4.3	7.3
SNF	WSH-PHI	NBC	9.2	-26%	16.55M	-28%	4.6	3.2	5.7
Early DH	DAL-NYG (85%)	FOX	7.9	-5%	13.92M	-4%	3.4	2.2	4.3
Late DH	AZ-LAR (73%)	CBS	7.4	-13%	13.51M	-9%	3.4	2.4	4.15
Early DH	PIT-CLE (71%)	CBS	7.4	-1%	13.14M	+5%	3.35	2.4	4.1

# Model Results: Initial Formulation

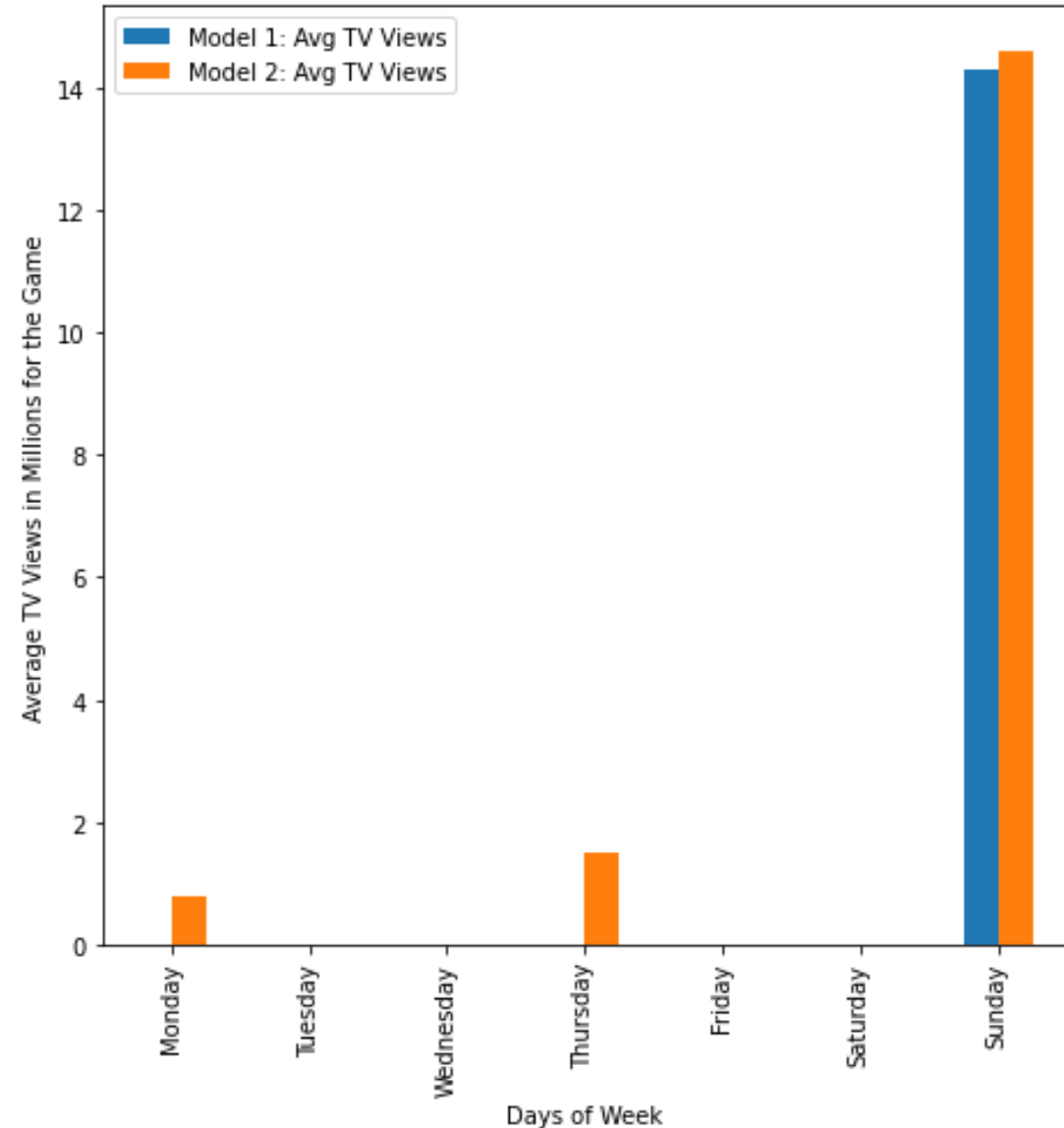
Week / Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Team
1							Home Game	Los Angeles Rams
2							Away Game	Arizona Cardinals
3				Away Game				Tampa Bay Buccaneers
4	Home Game							Cincinnati Bengals
5							Away Game	Los Angeles Rams
6							Home Game	Green Bay Packers
7							Home Game	Kansas City Chiefs
8	B	Y	E		W	E	E	K
9							Away Game	Las Vegas Raiders
10							Home Game	Atlanta Falcons
11							Home Game	San Francisco 49ers
12							Away Game	Washington Football Team
13							Home Game	San Francisco 49ers
14							Away Game	Arizona Cardinals
15							Away Game	New Orleans Saints
16							Home Game	Los Angeles Chargers
17							Away Game	Carolina Panthers
18							Away Game	Denver Broncos

# Model Results: New Formulation

Week / Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Team
1							Home Game	Baltimore Ravens
2							Home Game	Los Angeles Rams
3							Away Game	Arizona Cardinals
4							Away Game	Atlanta Falcons
5							Home Game	Los Angeles Rams
6	B	Y	E	W	E	E	K	
7							Home Game	Tennessee Titans
8							Away Game	Green Bay Packers
9							Away Game	Carolina Panthers
10							Home Game	San Francisco 49ers
11							Home Game	Washington Football Team
12				Away Game				Tampa Bay Buccaneers
13	Away Game							San Francisco 49ers
14							Home Game	Pittsburgh Steelers
15							Away Game	Arizona Cardinals
16							Away Game	New Orleans Saints
17							Home Game	Cleveland Browns
18							Away Game	Cincinnati Bengals

# Comparison of Television Views :

## Model 1 Vs Model 2





# Recommendations and Conclusions

- Scheduling was feasible for a single team and using given constraints
- Scheduling was made at the league level and not at team level
- Replicating it to other 31 teams will increase the complexity and the constraints involved.
- Extrapolating this design for the league would be difficult and would require more time.



**THANK YOU!**