Introduction

The NFL, otherwise known as the National Football League, is a professional football association in The United States of America. It is widely considered one of the most competitive and lucrative sports leagues, but also businesses, in the world [3]. Its combination of television contracts, ticket sales, merchandise, as well as national and international reach make it attractive for partnerships, and a role model for other leagues and sports to follow.

Currently, there are 32 teams in the NFL. These 32 teams are split evenly into 2 conferences, the American Football Conference (AFC) and the National Football Conference (NFC). These conferences are then further divided into 4 divisions of 4 teams each (AFC: North, East, South, West, and NFC: North, East, South, West) [5]. The idea of this division structure has been in effect since the early 1930s when the league was divided into two conferences to accommodate its quick expansion, however, the full realignment into the league of eight balanced divisions of 32 teams was not cemented until 2002 [1,4].

NFL regular seasons typically range from mid-September to late January. Within these dates, each team plays a fixed number of games against a subset of the other teams across the league. The standings after these 272 games determine the "playoff picture", a tournament-style bracket of games to be played to determine the league's champion for that year (The Superbowl Champion) [5]. It is often debated in sports which league trophy is most challenging to win, and due to the "sudden death" nature of the Superbowl playoffs, the NFL's is often at the top of the list in those conversations (each playoff series is decided in one game - the winner moves on, the loser goes home).

Description of the Problem

As mentioned in the introduction, the NFL is a popular, successful, growing sports league however that does not mean there are no improvements to be made [3]. Year over year a larger emphasis is put on the environmental saving which can be afforded by adjusting how we, as humans, exist. This includes day-to-day tasks such as our home's energy efficiency or the movement of electric vehicles but also seeps into how businesses conduct themselves. In recent years, we have witnessed a significant shift to a hybrid work environment where possible. This originally was done to reduce the spread of a global pandemic, but undoubtedly has had significant positive environmental impacts. We argue that there may be a better way in which the NFL could be planned and structured to help do their part in reducing their environmental impact, and set an example for sports leagues around the world. In this paper, we aim to find an optimal schedule for an NFL regular season, subject to several operational constraints to minimize the total distance

traveled by teams across the league. This may include minor changes to the restrictions on how the schedule is made, but will ultimately be a case study of how the environmental impact of a professional sports league could be lessened.

Currently, games are divided to give a set number of divisional games as well as inner conference games and opposing conference games [5]. We argue that this may be an outdated approach and that with a schedule more based on environmental and economic viability, the fairness and integrity of the schedule can be upheld while also finding significant savings. By nature of the program, teams closer together geographically will play against one another more frequently, similar to how the divisions currently operate, but in a more optimized manner. The divisions are currently loosely based on geographic location, but since the league was not created overnight, the expansion into various American cities has left divisions in a relatively unorganized state. For example, the AFC East consists of the Buffalo Bills, New York Jets, New England Patriots, and Miami Dolphins. Buffalo, New York, and New England are relatively close in proximity, but Miami is hundreds of miles away, and considering that most games are played against division opponents, this inefficiency is exacerbated throughout an entire NFL schedule. This is not the only case of such inefficiencies, and if the league further expands it may only worsen. The solution from our perspective lies in a computer model based on minimizing distance and letting the model create "optimal" divisions while upholding the basic constraints on game numbers and distributions.

Limitations

For this formulation, we will consider all general scheduling constraints and related features of how the NFL currently develops its plan, however, we will have the following limitations:

- We will not consider the implications and connections of television and broadcast contracts between the NFL and their partners.
- We are not considering the constraint of scheduling around other events (concerts, other sporting events, cultural events, other entertainment events, etc) in the stadiums of the NFL teams.
- We are not considering the "levels", or performance, of teams in previous seasons as a way to create the schedule.
- As mentioned above, we are not enforcing the current specific divisional structure, but modeling the constraints to create the optimal division of games.

The NFL's professional scheduling methods are highly confidential due to their immense value to the league and its stakeholders [1]. It is a tedious process that is done every year with the help of numerous cloud computers and scheduling experts [5]. The process takes months of iterative work and tweaking of computer-generated schedules to get the perfect blend season after season. In the following section, we outline our approach to this problem, which aims to produce an equitable schedule for all teams while meeting as many constraints as possible.

Formulation of the Problem

Data

The information pertaining to creating the NFL schedule was obtained directly from the NFL, namely operations.nfl.com [5]. The data collected includes the number of weeks in a season, the number of teams in the NFL, the teams in each conference in the NFL, and the number of games each team will play in a season.

The distances between cities used in our objective function calculation were sourced from a matrix on nflfootballstadiums.com [8].

- Let N be the set of potential game weeks from the first week to the last week, $N = \{1, 2, ..., n\}$.
- Let T be the set of teams in the NFL, $T = \{1, 2, ..., t\}$.
- Let C be the set of conferences in the NFL, $C = \{AFC, NFC\}$.
- Let C_i be the set of teams in the same conference as team i, $\forall$i $\in$ T.
- Let g be the number of games each team will play in a season.

In the 2024-2025 NFL season, we have the following values for our data:

- $n = 18$, since there are 18 available weeks for games to be scheduled (each team plays one game per week excluding 1 bye week throughout the season where they do not play).
- $t = 32$, since there are 32 teams in the NFL.
- $g = 17$, since teams play 17 games in each regular season.
- A matrix of distances (in miles) between every pair of stadiums in the NFL (entry $d_{i,j}$ is the distance between the stadiums of team i and team j).

Decision Variables

- Let $x_{i,j,w}$ be a binary variable which is 1 if team i plays against team j, at team j's stadium, in week w, and 0 otherwise.

Objective Function

Minimize the total distance traveled (multiply by two to minimize the total round trip distance traveled):

$$\text{Minimize: } \sum_{i=1}^{t} \sum_{j=1, j\neq i}^{t} \sum_{w=1}^{n} 2 \cdot d_{i,j} \cdot x_{i,j,w}$$

Constraints

- Each team plays exactly 17 games

$$\sum_{w=1}^{n} \sum_{i=1, i\neq j}^{t} (x_{i,j,w} + x_{j,i,w}) = 17, \quad \forall j \in T$$

- Each team plays 8 or 9 home games and the remaining games away

$$\sum_{w=1}^{n} \sum_{i=1, i\neq j}^{t} x_{i,j,w} \leq 9, \quad \forall j \in T$$

$$\sum_{w=1}^{n} \sum_{i=1, i\neq j}^{t} x_{j,i,w} \leq 9, \quad \forall j \in T$$

- Each team only plays one game per day

$$\sum_{j=1}^{t} x_{i,j,w} + \sum_{j=1}^{t} x_{j,i,w} \leq 1, \quad \forall i \in T : i \neq j, \quad \forall w \in N$$

- Team i and j cannot play more than once per week

$$x_{i,j,w} + x_{j,i,w} \leq 1, \quad \forall i, j \in T : i \neq j, \quad \forall w \in N$$

- Balanced distribution of home and away games between two specific teams

$$\sum_{w=1}^{n} (x_{i,j,w} - x_{j,i,w}) \leq 1, \quad \forall i, j \in T$$

- Each matchup pair can have a maximum of 3 games

$$\sum_{w=1}^{n}(x_{i,j,w} + x_{j,i,w}) \leq 3, \quad \forall i, j \in T : i \neq j$$

- Further restriction that teams in opposing conferences can play against each other at most once

$$\sum_{w=1}^{n}(x_{i,j,w} + x_{j,i,w}) \leq 1, \quad \forall i \in T, \forall j \notin C_i$$

- No team can play the same opponent for two consecutive weeks

$$\sum_{w=1}^{n-1}(x_{i,j,w} + x_{i,j,w+1} + x_{j,i,w} + x_{j,i,w+1}) \leq 1, \quad \forall i, j \in T : i \neq j$$

- No team can play more than 4 consecutive games at home or away in consecutive weeks

$$\sum_{i=1, i\neq j}^{t}(x_{i,j,w} + x_{i,j,w+1} + x_{i,j,w+2} + x_{i,j,w+3}) \leq 4, \quad \forall j \in T$$

$$\sum_{i=1, i\neq j}^{t}(x_{j,i,w} + x_{j,i,w+1} + x_{j,i,w+2} + x_{j,i,w+3}) \leq 4, \quad \forall j \in T$$

- Integrality constraint of the decision variables

$$x_{i,j,w} \in \mathbb{Z}, \quad \forall i, j \in T : i \neq j, \quad \forall w \in N$$

- Non-negativity constraint of the decision variables

$$x_{i,j,w} \geq 0, \quad \forall i, j \in T : i \neq j, \quad \forall w \in N$$

Analysis of Solutions

Main Solution

After implementing the above mathematical model in Gurobi, specifying the exact NFL teams, conferences, and distances between stadiums in the distance matrix (Appendix: Figure 2) we arrive at the full schedule solution outlined in (Appendix: Exhibit 1). To ensure computational integrity we validated the output schedule in Excel (Appendix: Exhibit 2) with various schedule breakdowns and validity checks.

One notable realization about our solution is that the New York Jets and New York Giants do not play against each other. These two teams play in the same stadium. When they play against each other, the travel distance is zero since they are both playing at home. We believe that the rationale for this observation is that it may be more efficient to place these two teams against other opponents in such a way that allows for the overall reduction in travel distances for the entire league. The travel savings from scheduling this game, which involves no distance between the teams, are less than the potential benefits of using that slot to reduce travel for other games.

The optimal output brings the total distance traveled under this proposed schedule to 349,354 miles with an average of approximately 10,917 miles traveled per team throughout the season. According to CBS Sports and Sports Illustrated, for the 2024-2025 NFL regular season, the total projected distance traveled is 597,408 miles (or an average of 18,669 miles per team) [2,7]. Thus we find the model results in distance savings of approximately 41.5%.

Not only is this change significant, but it forces one to consider the downstream effects that changes of this magnitude could bring. The schedule allows teams to continue playing similarly to the way the schedule is arranged now, but with an optimized plan for the inner-conference match-ups which collectively limits the round trip distance traveled for all teams. These levels of savings certainly would reduce the environmental impacts and carbon footprint of the NFL as a whole, but also have impacts seen by all stakeholders. Less travel puts less burden on teams, staff, and players from a logistics and recovery standpoint. The schedule also upholds the current conferences which house the most marquee match-ups but increases the frequency with which close proximity teams and cities face off leading to more livid rivalries and increased entertainment, from a fan perspective, across the league.

Alternative Solution with No Conferences

In our main solution, we removed divisions and found that less travel distance was required. We will now consider the solution solved by the model without the constraint requiring conferences, fully freeing the model to pick matchups which minimize total travel distance. Namely, we remove the constraint:

$$\sum_{w=1}^{n}(x_{i,j,w} + x_{j,i,w}) \leq 1, \quad \forall i \in T, \forall j \notin C_i$$

The new objective value is 264,768 miles, 84,586 miles less than the objective value of the main problem (Appendix: Exhibit 3). This objective value represents a 55.7% savings compared with the current schedule proposed by the NFL, with additional savings of 14.2% compared to the solution obtained in the main problem.

The trade-off in the gain from this solution is that we are removing an inordinate amount of familiarity for fans as stakeholders. The removal of divisions in our main problem is not a large departure from the current way in which the NFL creates the schedule. In our main solution, the large majority of games for each team comes with their conference which includes their divisions from the NFL's proposed schedule. This means inner division and inner conference rivalries are upheld, and those teams are likely to play once or more throughout the season. However, with this alternative solution, the conference game requirement is removed and in some cases teams could play almost exclusively against teams in the opposing conference, sacrificing the history of sought-after matchups and rivalries.

Therefore, the main problem is assessed to be a more acceptable solution to the problem of minimizing travel distance while upholding the current ideals of the NFL.

Conclusion

As seen throughout the formulation, computation, and analysis section of this report, using the data obtained from the NFL, we created an integer program whose constraints enforce a feasible NFL schedule and whose objective function minimizes travel distance.

The main difference between our model and the schedule developed by the NFL is the absence of strict and structured divisions. This was an intentional restriction made to propose a schedule focused on a balance of environment and economic viability while also upholding the main structure and integrity of the NFL schedule known by millions. We also explored a model where conferences were removed completely as well and analyzed

the differences in the solutions. Although there were additional savings made in travel distance by removing the conference, we decided the opportunity cost was too high. The NFL is successful currently for all of its stakeholders, but we felt that removing that extra level of familiarity and structure to the league would diminish the product to the fan base.

The model we suggest creates sizable distance savings of 41.5% relative to the current schedule created by the NFL. Firstly, the monetary savings are notable. As travel is typically conducted by private jet, these savings from travel costs would be substantial. These savings would not just be seen at the team level but throughout all stakeholders. If teams spend less on travel, they can charge less for tickets, making games more accessible for fans who are familiar with the game, as well as the next generation. Secondly, the environmental savings are significant. In today's age society is trending towards more environmentally friendly business solutions. Since the NFL is a model organization in the realm of sports leagues, aligning with these environmental ideals is of great value and importance. It could motivate other professional leagues to introduce similar changes and restrictions leading to more savings.

In conclusion, a departure from a structured and strict division-based schedule to a more fluid model could prove advantageous for the NFL and its stakeholders. As mentioned, other factors should be considered if this solution were to be implemented in the NFL (TV contracts, other events, etc), but those challenges are not insurmountable. However, sacrifices and growing pains are associated with the changes, and the economic and environmental savings cannot be ignored. The analysis in this report recommends this shift due to the aforementioned benefits.

Appendix

Map of NFL Teams

Figure 1: Map of NFL teams across the United States.

Schedule Summary

Week 1: New York Giants at Cleveland Browns
Week 1: Oakland Raiders at Miami Dolphins
Week 1: Buffalo Bills at Detroit Lions
Week 1: New York Jets at Houston Texans
Week 1: Chicago Bears at Minnesota Vikings
Week 1: Dallas Cowboys at Atlanta Falcons
Week 1: Baltimore Ravens at Carolina Panthers
Week 1: Denver Broncos at Green Bay Packers
Week 1: Jacksonville Jaguars at Tennessee Titans
Week 1: New England Patriots at Los Angeles Chargers
Week 1: Kansas City Chiefs at Arizona Cardinals
Week 1: Cincinnati Bengals at Philadelphia Eagles
Week 1: New Orleans Saints at Washington Commanders

Exhibit 1: Summary of schedule created with Gurobi
The remainder of the schedule can be accessed with the additional materials submitted with this report.

Exhibit 2: Schedule validity checks (Excel)
The Excel sheet used for validity checks can be found in the additional materials submitted along with this report.

Exhibit 3: Alternative Solution Schedule
The schedule created by Gurobi for this alternative solution can be found in the additional materials submitted with this report.

Distance Matrix

Washington, D.C.	Tampa, FL	Seattle, WA	SanFrancisco, CA	San Diego, CA	St. Louis, MO	Pittsburgh Pa	Philadelphia PA	Oakland CA	New York, NY	New Orleans, LA	Nashville, TN	Foxboro, MA	Minneapolis, MN	Miami, FL	Kansas city, MO	Jacksonville, FL	Indianapolis, IN	Houston, TX	Green Bay, WI	Detroit, MI	Denver, CO	Dallas, TX	Cleveland, OH	Cincinnati, OH	Chicago, IL	Charlotte, NC	Buffalo, NY	Baltimore, MD	Atlanta, GA	Phoenix, AZ	
2362	2184	1513	750	358	1517	2136	2420	742	2481	1548	1687	2700	1805	2390	1360	2072	1764	1188	2017	2074	904	1077	2085	1876	1819	2107	2274	2366	1868		Phoenix, AZ
636	455	2705	2618	2166	549	676	782	2468	869	473	248	1074	1129	661	801	344	531	800	927	735	1403	792	726	476	717	238	910	679		1868	Atlanta, GA
38	960	2775	2840	2724	849	246	104	2820	192	1142	707	392	1121	1109	1087	763	600	1470	918	532	1690	1399	377	521	708	441	370		679	2366	Baltimore, MD
384	1276	2612	2677	2632	749	217	414	2661	400	1254	706	455	958	1425	995	1080	508	1513	753	277	1546	1393	197	442	545	695		370	910	2274	Buffalo, NY
397	581	2827	2759	2405	704	438	543	2725	631	713	426	835	1173	730	956	385	575	1041	994	675	1559	1031	520	476	761		695	441	238	2107	Charlotte, NC
701	1176	2062	2146	2105	294	467	768	2132	797	935	472	985	409	1382	532	1065	184	1108	208	283	1015	936	346	302		761	545	708	717	1819	Chicago, IL
517	935	2368	2407	2234	350	292	576	2385	636	820	274	841	714	1141	597	803	116	1079	506	261	1200	958	253		302	476	442	521	476	1876	Cincinnati OH
370	1101	2413	2478	2437	560	136	437	2462	466	1070	521	639	760	1250	806	904	319	1328	553	171	1347	1208		253	346	520	197	377	726	2085	Cleveland, OH
1362	1161	2208	1827	1375	635	1246	1501	1725	1589	525	667	1755	999	1367	554	1049	913	241	1149	1218	887		1208	958	936	1031	1393	1399	792	1077	Dallas, TX
1686	1862	1329	1271	1092	855	1460	1744	1266	1799	1409	1162	1987	924	2069	603	1751	1088	1127	1105	1284		887	1347	1200	1015	1559	1546	1690	1403	904	Denver, CO
526	1194	2350	2415	2373	549	292	592	2398	622	1079	535	707	697	1401	795	1060	318	1338	490		1284	1218	171	261	283	675	277	532	735	2074	Detroit, MI
906	1384	1939	2236	2181	497	669	968	2229	998	1135	680	1192	280	1594	626	1273	393	1390		490	1105	1149	553	506	208	994	753	918	927	2017	Green Bay, WI
1433	995	2449	1938	1487	863	1366	1572	1921	1660	360	859	1835	1240	1201	795	884	1033		1390	1338	1127	241	1328	1079	1108	1041	1513	1470	800	1188	Houston, TX
596	990	2249	2290	2122	239	370	655	2275	715	826	288	950	596	1196	485	879		1033	393	318	1088	913	319	116	184	575	508	600	531	1764	Indianapolis, IN
720	196	3052	2822	2370	896	822	866	2792	953	556	594	1142	1477	345	1148		879	884	1273	1060	1751	1049	904	803	1065	385	1080	763	344	2072	Jacksonville, FL
1083	1259	1872	1814	1695	252	857	1141	1803	1202	932	558	1434	441	1466		1148	485	795	626	795	603	554	806	597	532	956	995	1087	801	1360	Kansas City, MO
1065	274	3370	3140	2688	1214	1167	1211	3113	1299	874	915	1492	1794		1466	345	1196	1201	1594	1401	2069	1367	1254	1141	1382	730	1425	1109	661	2390	Miami, FL
1115	1588	1654	2055	2014	621	881	1181	2042	1211	1337	870	1392		1794	441	1477	596	1240	280	697	924	999	760	714	409	1173	958	1121	1129	1805	Minneapolis, MN
432	1367	3051	3117	3062	1193	572	295	3111	204	1510	1090		1392	1492	1434	1142	950	1835	1192	707	1987	1755	639	841	985	835	455	392	1074	2700	Foxboro, MA
676	705	2405	2311	2028	309	560	809	2300	890	534		1090	870	915	558	594	288	859	680	535	1162	667	521	274	472	426	706	707	248	1687	Nashville, TN
1106	668	2731	2298	1846	690	1108	1245	2268	1332		534	1510	1337	874	932	556	826	360	1135	1079	1409	525	1070	820	935	713	1254	1142	473	1548	New Orleans, LA
228	1150	2864	2929	2839	956	367	91	2908		1332	890	204	1211	1299	1202	953	715	1660	998	622	1799	1589	466	636	797	631	400	192	869	2481	New York, NY
2815	2902	804	12	492	2056	2578	2877		2908	2268	2300	3111	2042	3113	1803	2792	2275	1921	2229	2398	1266	1725	2462	2385	2132	2725	2661	2820	2468	742	Oakland, CA
140	1062	2835	2900	2779	895	306		2877	91	1245	809	295	1181	1211	1141	866	655	1572	968	592	1744	1501	437	576	768	543	414	104	782	2420	Philadelphia, PA
240	1019	2534	2599	2494	611		306	2578	367	1108	560	572	881	1167	857	822	370	1366	669	292	1460	1246	136	292	467	438	217	246	676	2136	Pittsburgh, PA
837	1008	2125	2066	1875		611	895	2056	956	690	309	1193	621	1214	252	896	239	863	497	549	855	635	560	350	294	704	749	841	549	1517	St. Louis, MO
2720	2481	1271	508		1875	2494	2779	492	2839	1846	2028	3062	2014	2688	1695	2370	2122	1487	2181	2373	1092	1375	2437	2234	2105	2405	2632	2724	2166	358	San Diego, CA
2834	2933	816		508	2066	2599	2900	12	2929	2298	2311	3117	2055	3140	1814	2822	2290	1938	2236	2415	1271	1827	2478	2407	2146	2759	2677	2840	2618	750	San Francisco, CA
2769	3164		816	1271	2125	2534	2835	804	2864	2731	2405	3051	1654	3370	1872	3052	2249	2444	1939	2350	1329	2208	2413	2368	2062	2827	2612	2775	2705	1513	Seattle, WA
916		3164	2933	2481	1008	1019	1062	2902	1150	668	705	1367	1588	274	1259	196	990	945	1384	1194	1862	1161	1101	935	1176	581	1276	960	455	2184	Tampa, FL
	916	2769	2834	2720	837	240	140	2815	228	1106	676	432	1115	1065	1083	720	596	1433	906	526	1686	1362	370	517	701	397	384	38	636	2362	Washington, D.C.

Figure 2: Distance between cities matrix used in computations.

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