Improving Formula 1 Sustainability by Ordering the F1 Season Calendar to Optimize for Carbon Emissions

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Abstract -- Formula One Racing (F1) travels across the globe, racing in more than 20 countries each year. While the series has placed an increased focus on environmental sustainability, the calendar order of the races in the season has not been optimized, leading to excess carbon emissions. This project determines the most emissions-efficient order of the Formula 1 Season Race calendar to reduce the organization's carbon footprint from transportation logistics. The calculations assumed all current contract agreements between Formula One Management and race promoters were considered null and void; all locations of races in each continent had the same relative weather conditions in each season; teams can only bring upgrades from the factory to the two races closest to them; and the teams traveled by air and used air-freight for equipment between race venues outside Europe. Within Europe, only ground transportation is used. We first specify the first race of the season as a starting point to build the optimized calendar. Then, a branch and bound algorithm to parse through the remaining races was used to add the next closest race to the calendar until all races were added. While the algorithm constructs the optimal race schedule, the simulation program tracks the distance traveled by plane or truck between subsequent races. The total distance traveled by each mode of transport is then multiplied by respective constants for carbon emissions per mile. Iterating over the yet unscheduled races helps arrive at the total carbon emissions from transportation emitted across a fully optimized season.

Introduction -- In 2019, Liberty Media, owner of Formula One Management (FOM), released a report on the environmental sustainability of the racing championship with an outline to limit the annual carbon footprint of the racing series. The report found that in 2019, Formula 1's carbon footprint was 256,551 tons of carbon dioxide [1]. Furthermore, an enormous 72.7 percent of those emissions come from logistics and business travel. The announced plan by Formula 1 only targeted emissions from the Formula 1 Race cars' power unit, event operations, and the operations within facilities and factories. When combined, their target only represented 27.3 percent of Formula 1's carbon emissions in 2019.

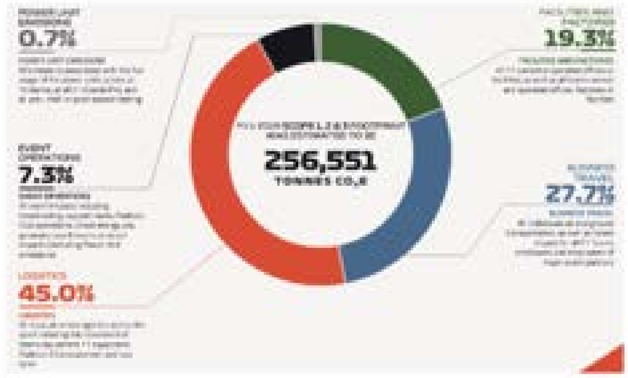

Fig. 1. Breakdown of annual carbon emissions of F1 by category.

As Formula 1 has not taken steps to address the more pressing problem of their logistics and business travel operations, this paper suggests an approach which would reduce Formula 1's carbon footprint in its transportation and logistical operations. In this paper we explore how the Formula 1 race season can be optimized to reduce the racing series' total annual carbon emissions. The race calendar included 19 races in 2014 and is now 24 races in 2024 – a 26 percent increase. This paper poses a new approach in the ordering of races within the calendar by using an advanced algorithm to calculate the distance between races, team headquarters, and airports. Our research aims to provide a more sustainable season calendar in Formula 1 to reduce the season's annual carbon footprint by reordering the races in the calendar to improve transportation efficiency.

Background/Literature Review -- Previous studies have investigated how to better optimize the Formula 1 Season Calendar. For example, an online video titled I Coded the Most Optimal Formula 1 Calendar, by Youtube user Off The Grid, generated a top-level distance optimized calendar by calculating the bee-line distance between each individual circuit [2]. In addition, Cambridge Kisby, an author for Motorsport Magazine [4] also created a distance optimized calendar, however it pre-grouped circuits not necessarily close to one another, leading to some unoptimized travel routes. Additionally, these and many other studies on the optimization of the F1 calendar do not take truck transportation between airports and races into account. Our research delves deeper by taking transportation between airports and circuits into account, as well as accounting for shipment of car and equipment upgrades. In addition, this research aims to optimize the season calendar for carbon emissions, rather than distance.

Methodology

(Data Sets) Before running the algorithm, data was gathered for the latitude and longitude coordinates of all circuits, their closest commercial airports, and each team's headquarters.

These data sets were gathered from Google Maps, and then stored in CSV formatted files. The latitude and longitude coordinates of all circuits can be seen in the labels of figures 2, 3, 4, and 5. The coordinates of airports were used to calculate driving distances through the use of Map Quest's API. The flying distances were calculated by finding the length of the straight line from one airport to another. The coordinates of team headquarters were also crucial as they helped with calculating the carbon emissions produced by the "upgrade period" rule we add to accurately calculate the carbon emissions produced from upgrade shipments.

Fig. 2. Numbered Labels of North and South American Circuits.

Fig. 3. Numbered Labels of European Circuits.

Fig. 4. Numbered Labels of Middle Eastern Circuits.

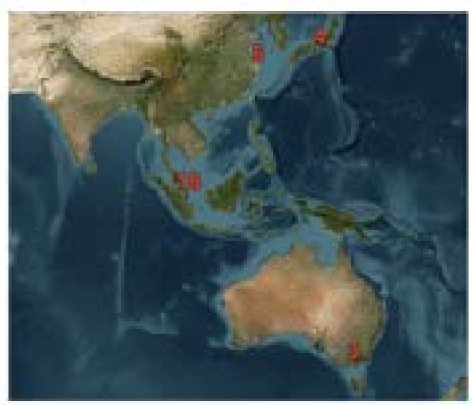

Fig. 5. Numbered Labels of East Asian and Australian Circuits.

(Algorithm) Given a starting race, distances from the airport of that first race are compared to those of all other race circuits. The closest airport is selected, and the corresponding race circuit is added to the calendar. This process is repeated until all 24 races are added. Thus, the starting city is key in determining the circuit's order. For example, if Bahrain, the first race of the

2024 season, is selected, it returns a different order than if Miami was selected as the first race. The algorithm was used to calculate the ideal calendar for each possible starting race.

(Distances) As each race is added to the calendar, the total flight distance is tracked. When the computation enters the European leg of the season, we keep track of the ground distances between circuits. After the algorithm generates the optimized calendar, we process the calendar again to add the driving distances between the airports and circuits of the non-European races. Note that the total driving distance between the airports and circuits of non-European races is not a constant value, as a fixed cost would not factor in the one-way distance between the airport and circuit of the non-European race prior to and directly following the European leg of races.

(Upgrade Transportation) Since the transportation of upgrades is an unpredictable input to this program, this paper proposes a new sporting regulation rule in which teams can only bring upgrades from the factory to the two races closest to them. These ”upgrade rules” limit the upgrades teams can bring across a full season in order to limit the carbon emissions emitted by transporting these upgrades from the team factories to circuits. As the distances of team headquarters to their closest two races is a constant value, this was calculated separate from the algorithm. The total distance of all the team headquarters to their two closest circuits is approximately 3877 miles, all traveled by truck. This constant is added to the distance calculations from the algorithm and the additional airport to circuit distances in order to obtain the total distance traveled by truck.

(Equipment) While Formula 1 has multiple kits of equipment stationed strategically around the globe, this research assumes that teams use one equipment kit for all 24 races.

(Emissions Calculations) The average airplane emission rate is estimated at 24.18 kilograms of CO2 per kilometer, while the average truck emission rate is estimated to be 0.01 kilograms per kilometer [5]. Using these constants, and the distance calculations produced by the algorithm, the total carbon emissions from the transportation of equipment across a full, distance-optimized Formula 1 Season Calendar was calculated.

(Repeated Trials) The algorithm was tested 24 times to find the optimized season race calendar, with the first race changing in each trial.

TABLE I
MOST EMISSION-EFFICIENT RACE ORDER - AUSTRALIA RACE 1

Optimized from Australia	
Round	Country
1	Australia
2	Singapore
3	China
4	Japan
5	Azerbaijan
6	Bahrain
7	Qatar
8	Abu Dhabi
9	Saudi Arabia
10	Hungary
11	Austria
12	Italy Imola
13	Italy Monza
14	Monaco
15	Spain
16	Belgium
17	Netherlands
18	United Kingdom
19	Canada
20	US Miami
21	US Texas
22	Mexico
23	US Las Vegas
24	Brazil

Results -- The most distance-optimal season schedule starts from a first race in Australia, which logged a total travel distance of approximately 37,442 miles, with 30,163 miles traveled by plane, and the other 7279 miles traveled by truck. This is substantially lower than that of the actual 2024 season calendar, which is ~120,829 miles. In addition, with the combined transportation of equipment of all 10 teams, the FIA (Fédération Internationale de l'Automobile), and FOM, the estimated emissions from the optimal race calendar (~28170 metric tonnes of CO_2) is significantly lower than that reported from the season calendar in 2019 (256,551 metric tonnes [1]), which included 3 races less than the 2024 schedule. This emission-efficient season schedule can be found in table I above, and a map of the emission-efficient route in figure 6 below.

Fig. 6. Emission-Efficient Calendar Route Visualization.

Conclusion -- This research attempted to prepare a Formula 1 season calendar by reordering races to lower carbon emissions traveled between races, helping Formula 1 get closer to their sustainability goals. To prepare the calendar, we implemented an algorithm that, given the first race, selects subsequent races based on specific criteria to lower emissions.

Several adjustments to the algorithm can improve the route selections and accuracies of the carbon emissions estimates. On the topic of route selections, the nature of the organization of the season calendar mimics that of the Traveling Salesman Problem. As a result, while we assumed that the branch and bound algorithm was the best approach to optimizing the calendar, there are certain scenarios in which this does not hold true. For example, in the most efficient race order (Table I), the Texas → Mexico → Las Vegas → Brazil sequence to end the season might not yield the shortest distance between all 4 races. Ultimately, while the branch and bound algorithm is useful as an attempt to solve this TSP-like problem, the limitations of the branch and bound algorithm means there could be an even more distance-optimal order between the races. In addition, this optimal race order in figure 6 assumes a uniform weather pattern throughout the year, and does not take continental weather patterns into consideration, which would become a problem towards the end of the Middle Eastern leg of the season due to increasing temperatures. Finally, the algorithm assumes team personnel do not travel back to team headquarters between races, which is not true. Many team personnel travel back and forth to Europe in between races, which contributes to a higher emissions output. Ultimately, this research has shown that there is an enormous potential for Formula 1 to greatly diminish its annual carbon footprint through the improvement of their logistics, instead of focusing on limiting the already meager emissions caused by the racing series's cars.

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