Optimizing Formula 1 Logistics

Sustainable Logistics Operations
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Executive Summary

- **Formula 1 Popularity and Environmental Concerns**: Recognized as one of the world's most popular sports with a cumulative audience of 1.5 billion per season, Formula 1 must align its logistics with global carbon reduction targets to achieve a sustainable future.

- **Current Logistical Inefficiencies**: The Official schedule leads to suboptimal logistics, significantly contributing to the sport's carbon footprint. While current initiatives emphasize developing biofuels, they do not support logistics optimization enough, raising questions about the sport's commitment to minimizing its overall carbon footprint.

- **Sequential Optimization Strategy**: Minimizing distances between races and selecting the most CO2-efficient transport modes (planes, boats, trucks) can cut emissions, using detailed distance, CO2, and time matrices for accurate planning.

- **Optimal Schedule Outcomes**: Implementing optimized schedules could lead to emissions reductions of more than 80% compared to the official schedule, along with significant cost savings.

- **Contract Schedule Efficiency**: Balancing contractual constraints with environmental goals, the contract schedule reduces emissions by 83.86% from the official schedule, highlighting a feasible path to sustainability.

- **Cost Extension**: Taking into account the price of the mode of transport shows a reduction in overall logistics costs, mainly due to the reduction in distance. Applying the European carbon tax to offset externalities shows the price that the FIA would have to pay to compensate for its negative externalities. The optimal schedule results in savings of almost $14 million or a reduction of 83.9% compared to the Official Schedule.

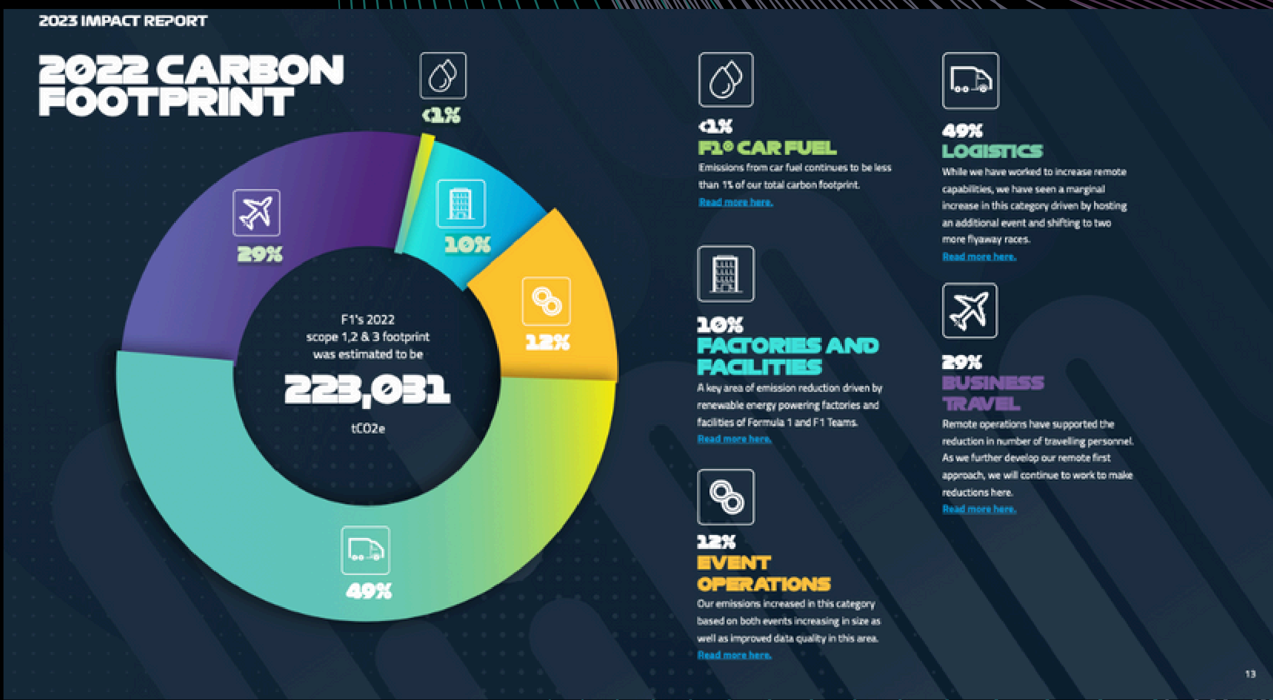
- **Private Jet Extension**: If we look beyond freight logistics and take into account the driver's private jet, we see a drastic reduction in CO2 emissions for the optimum schedule compared with the official one.

- **Future Recommendations for 2025**: Adopting the optimal 2025 schedule and incorporating train transportation for European races can further reduce CO2 emissions, achieving a more compact season with substantial environmental and financial benefits.

Description of the situation under study

Formula 1, recognised as one of the world's most popular sports with a cumulative audience of 1.5 billion people per season [1], raises questions about its alignment with global targets for reducing carbon emissions towards a Net-Zero future. However, rather than calling into question the legitimacy of the championship, our study suggests looking for logistical solutions to improve its environmental impact.

The current organisation of Formula 1 championship circuits shows that logistics are not very well optimised, as exemplified by the organisation of the Montreal Grand Prix in the middle of the European tour. This organisation makes a significant contribution to the sport's carbon footprint, with logistics and private travel by drivers and their teams accounting for 68% of the championship's total CO2 emissions, or around 153,891 tonnes of CO2 in 2022. [2]



According to their 2023 Impact Report, it appears that current initiatives focus solely on the development of sustainable fuels, such as biofuels, with no apparent plans to optimise or reduce event logistics. This strategy raises questions about the championship's willingness or ability to really minimise its overall carbon footprint.

Part of the answer can be found by analysing the management of the rights and organisation of Formula 1 races, which were handed over by the FIA (Fédération Internationale de l'Automobile) to the Formula One Group in 1987 for a period of 100 years, a structure set up by Bernie Ecclestone and currently owned by the Liberty Media group. This separation of powers illustrates why the FIA has little influence over the planning of the Formula 1 racing calendar, which is dictated by the commercial interests of the holding companies that own the Formula One Group.

Description of the situation under study

This commercial orientation has led to a substantial increase in the cost of contracts to host a Grand Prix, rising from $10 million in 2010 to more than $50 million in 2024. In addition, there has been a significant increase in the number of races per season, with growth of 50% compared to 1990-1999 and 26% since the 2010s [3]. This expansion raises additional concerns about the logistical and environmental challenges associated with such a busy calendar.

Faced with the challenges posed by the current organisation of Formula 1 races, our strategy does not seek to call into question the number or location of races. Instead, we adopt a pragmatic approach focused on optimising the calendar to minimise environmental impact. This optimisation takes into account seasonal constraints, for example, avoiding the organisation of Grands Prix in Europe in early spring or late autumn, as well as calendar constraints such as the summer break, a period when audiences are generally less optimal. This optimization also takes into account the fact that the championship has a three-month break (December, January, February) to allow the constructors to develop the cars for the following season.

To achieve this objective, we have developed a sequential optimization strategy. Our sequential optimisation reorganises the races so as to minimise the distances travelled between consecutive events, and then chooses the transport mode mix that minimises CO_2 emissions, given the calendar constraints. This approach provides practical, achievable solutions for significantly reducing the carbon footprint of the championship.

[1] 2021 F1 Viewership: Over 100 Million Viewers for the Grand Finale," Motors Inside. Available at: https://www.motorsinside.com/f1/actualite/26335-audiences-de-la-f1-2021-plus-de-100-millions-de-telespectateurs-pour-le-grand-final.html
[2] "Net Zero Carbon Update," Formula 1 Corporate. Available at: https://corp.formula1.com/countdown-to-zero/net-zero-carbon-update/
[3] Formula 1 Grand Prix," Wikipedia. Available at: https://fr.wikipedia.org/wiki/Grand_Prix_de_Formule_1#%C3%89preuve_du_championnat_du_monde_par_saison.

Description of the data

- ## Distance Matrices

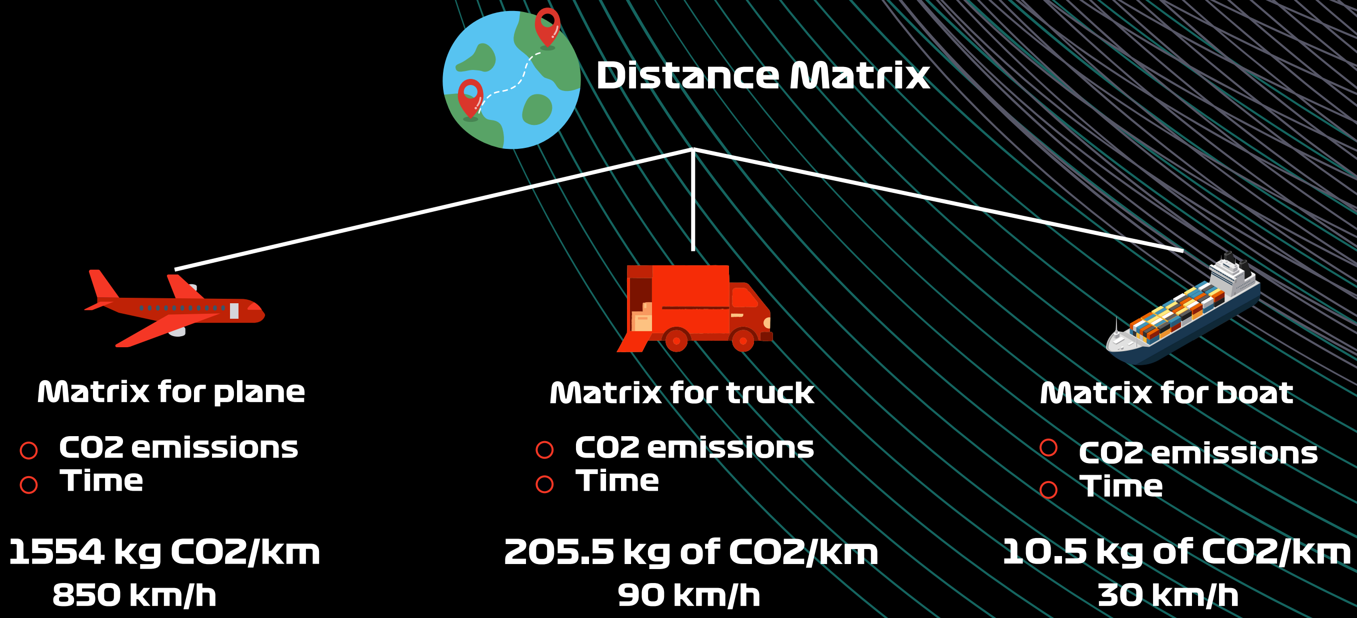
Three City-Distance Matrices were created for different transport modes: plane, boat, and truck. The plane matrix served as the base for the others. After conducting several calculations with real distances, the boat matrix was developed by adjusting distances by factors of 1.6 for long routes and 1.3 for short ones. The truck matrix distances were roughly 1.3 times those of planes. All matrices were designed to reflect only feasible routes realistically, avoiding non-viable options in optimization by asigning them high values.

- ## CO2 Matrices

Three CO2 emissions Matrices were created for planes, trucks, and ships by applying specific factors to distance matrices and referencing data on emissions per tonne-kilometer from Statista [4]. For a transport weight of 1500 tonnes, the emissions are calculated as follows: air cargo produces 1554 kg CO2 per km, trucks generate 205.5 kg CO2 per km, and maritime shipping results in 10.5 kg CO2 per km. These calculations, detailed in the Appendix, ensure the accuracy of our CO2 estimates for different transport modes, leveraging standardized data for consistency.

- ## Time Matrices

Three Time Matrices were created for each mode of transport by dividing the city-distance matrices by their respective speed factors: 850 km/h for cargo planes [5], 90 km/h for trucks [6], and 30 km/h for cargo ships [7].



[4] Statista. (n.d.). EU-27: Average GHG emissions by mode of freight transport. Retrieved May 21, 2024, from https://www.statista.com/statistics/1282257/average-ghg-emissions-in-the-eu-by-freight-transport-mode/
[5] Wikipedia. (n.d.). Boeing 747. Wikipedia. Retrieved May 21, 2024, from https://fr.wikipedia.org/wiki/Boeing_747
[6] Sécurité Routière. (n.d.). Plafonnement des vitesses maximales autorisées des poids lourds de moins de 12 tonnes. Sécurité Routière. Retrieved May 21, 2024, from https://www.securite-routiere.gouv.fr/actualites/plafonnement-des-vitesses-maximales-autorisees-des-poids-lourds-de-moins-de-12-tonnes-90
[7] Universalis. (n.d.). Transport de cargaisons. Encyclopædia Universalis. Retrieved May 21, 2024, from https://www.universalis.fr/encyclopedie/navires-navires-de-commerce/2-transport-de-cargaisons/

Description of the data

- **Private Jet Matrix**

In the Formula 1 championship impact report, it is noted that 'business travel', encompassing all individual air and land transport as well as the impact of hotel stays for all F1 teams and partners, accounts for 27% of total emissions. To examine these emissions, particularly those from private jets, we applied a calculation factor of 3 kg of CO2 per kilometer [8].

- **Direct transportation costs**

We aimed to estimate the cost of each of our transportation solutions as it is a crucial metric to consider. Calculating exact costs is challenging due to Formula 1's size and the nature of its logistics contracts, which are often proprietary and complex. However, for estimation purposes, we have derived average costs that allow us to compare different transportation options. These values were sourced from a 2021 report commissioned by the Netherlands Institute for Transport Policy Analysis (KiM) and developed by Panteia. [9]

- Truck: $0.4 per tonne-kilometer
- Boat: $0.0014/t-km
- Plane: $0.19/t-km
- Train: $0.045/t-km

- **Costs of emitting carbon**

For our analysis of the cost of emitting carbon dioxide, we relied on data from the European Union Emissions Trading System (EU ETS). According to the Carbon Price Viewer [10], the current cost of emitting one tonne of carbon dioxide in Europe is approximately 70 euros, which translates to about 75 US dollars. The Carbon Price Viewer provides real-time updates and trends on carbon prices, helping us stay informed about the fluctuations and current rates.

- **Train carbon intensity**

As one of our extensions consists in incorporating the train in Europe for the 2025 schedule, we included the CO2 emissions for the train. The emission factor is 24 grams of CO2 per tonne-kilometer, so 36 kg of CO2 per km for transporting the 1500 tonnes needed (11).

[8] CO2 Emissions of Private Aviation in Europe," Greenpeace Austria. March 2023. Available at: https://greenpeace.at/uploads/2023/03/co2_emissions_of_private_aviation_in_europe_def.pdf
[9] Panteia, "Cost Figures for Freight Transport - Final Report". January 2023
[10] Carbon Price Viewer - Sandbag Climate Campaign. Available at: https://sandbag.be/carbon-price-viewer/
[11] Statista. (n.d.). EU-27: Average GHG emissions by mode of freight transport. Retrieved May 21, 2024, from https://www.statista.com/statistics/1282257/average-ghg-emissions-in-the-eu-by-freight-transport-mode/

Sequential Optimization

Sequential optimization rearranges race schedules to minimize the distances between consecutive events. Then, it selects the mix of transportation modes that minimizes CO2 emissions, considering the calendar limitations. Next, following this procedure, different optimal schedules will be determined under varying constraint levels. Their respective results will be compared to those of the official schedule of 2023.

Official Schedule 2023

R1 SAKHIR 03-05 MAR	R9 MONTREAL 16-18 JUN	R17 SUZUKA 22-24 SEP
R2 JEDDAH 17-19 MAR	R10 SPIELBERG 30 JUN - 2 JUL	R18 LUSAIL 06-08 OCT
R3 MELBOURNE 31 MAR - 2 APR	R11 SILVERSTONE 07-09 JUL	R19 AUSTIN 20-22 OCT
R4 BAKU 28-30 APR	R12 BUDAPEST 21-23 JUL	R20 MEXICO CITY 27-29 OCT
R5 MIAMI 05-07 MAY	R13 SPA-FRANC. 28-30 JUL	R21 SAO PAULO 03-05 NOV
R6 IMOLA 19-21 MAY	R14 ZANDVOORT 25-27 AUG	R22 LAS VEGAS 16-18 NOV
R7 MONACO 26-28 MAY	R15 MONZA 01-03 SEP	R23 ABU DHABI 24-26 NOV
R8 BARCELONA 02-04 JUN	R16 SINGAPORE 15-17 SEP	

Regarding the Depot, since most F1 teams are based in the UK, we have decided to set its location there for all cases. In light of this, the total distance for the Official Schedule 2023 is 157,928.56 km accounting for the journeys from and to the UK's base, truck transportation utilized for European travel and planes for other destinations. Total CO2 emissions sum up to 218,277.15 tonnes.

	Total Distance	Total CO2 Emission
Official Scedule 2023	157,929 km	218,277 tonnes

Sequential Optimization

The first optimization provides the optimal schedule that minimizes the total distance by only accounting for the cities where races take place, hence not considering where the depot is located.

Optimal Schedule (no Depot)

1 Schedule calculation. TSP. Distance minimization.

To optimize the travel schedules for the F1 season, we initially employed the Traveling Salesman Problem (TSP) algorithm, considering only the distances covered by air travel. This approach served as the first step in our sequential optimization strategy, aimed at reducing CO2 emissions by later incorporating different modes of transportation.

To simplify our model, we have introduced a fictitious depot whose distances from all the cities where a Grand Prix takes place are zero, so that we do not have to consider the departure and return to the base of the teams. The optimal schedule obtained that minimizes distance is the one that follows:

```
Optimal Schedule (without Depot):
['Melbourne','Singapore','Suzuka','Baku','Yas Marina','Lusail','Sakhir',
'Jeddah','Budapest','Spielberg','Imola','Monza','Monaco','Barcelona','Spa
Francorchamps','Zandvoort','Silverstone','Montreal','Las Vegas','Austin',
'Mexico City','Miami','São Paulo']
```

2 Definition of Means of Transport to Minimize CO2 Emissions

In this second step, we aim to minimize the CO2 emissions of the optimized schedule. To achieve this, we have considered three potential modes of transportation between cities prioritizing them all based on their lower CO2 emissions: boat, truck, and plane, in that order. We have also introduced the location of the Depot, so that total distance and CO2 emissions are comparable with the other schedules. Additionally, we have imposed a constraint that only routes taking less than 10 days in total will be considered, aligning with the maximum two-week interval between Grand Prix events.

It is important to note that we have neglected the additional transportation distance from the nearest port (and airport) to the destination because most cities are not located too far from ports. For those cities that are located far from ports, the boat option was not considered feasible. After applying these considerations and conducting the optimization, these are the outcomes:

- UK => Melbourne by plane
- Melbourne => Singapore by boat
- Singapore => Suzuka by boat
- Suzuka => Baku by plane
- Baku => Yas Marina by truck
- Yas Marina => Lusail by boat
- Lusail => Sakhir by boat
- Sakhir => Jeddah by boat
- Jeddah => Budapest by boat
- Budapest => Spielberg by truck
- Spielberg => Imola by truck
- Imola => Monza by truck
- Monza => Monaco by truck
- Monaco => Barcelona by truck
- Barcelona => Spa Francorchamps by truck
- Spa Francorchamps => Zandvoort by truck
- Zandvoort => Silverstone by boat
- Silverstone => Montreal by boat
- Montreal => Las Vegas by boat

Sequential Optimization

Given the schedule and the means of transport that will be used to go from one city to the following one, it is now possible to calculate the total distance and total CO2 emitted in this Optimal Schedule. These are the results:

	Total Distance	Total CO2 Emission
Official Scedule 2023	157,929 km	218,277 tonnes
Optimal Schedule (no Depot)	85,214 km	41,289 tonnes

The total distance for this Optimal Schedule amounts to 85,214 km, which is **46% reduction** compared to that of the Official Schedule. Regarding total CO2 emissions, they amount to 41,289 tonnes, which represents a **81% reduction** in emissions compared to those generated under the Official Schedule.

3 Definition of GP Dates

The next step is to establish the dates for each Grand Prix. This process incorporates the following constraints:

- The first race takes place on March 5th,2023.
- Grand Prix events occur on Sunday.
- If travel between cities takes less than 3 days, races are spaced 1 week apart.
- If travel duration falls between 3 and 10 days, races are spaced 2 weeks apart.
- No races are scheduled for January, February, August, and December.

After applying all these conditions, the scheduled dates are as follows:

Round	City	Dates
R1	MELBOURNE	03-05 MAR
R2	SINGAPORE	17-19 MAR
R3	SUZUKA	31 MAR - 2 APR
R4	BAKU	07-09 APR
R5	ABU DHABI	14-16 APR
R6	LUSAIL	21-23 APR
R7	SAKHIR	28-30 APR
R8	JEDDAH	05-07 MAY
R9	BUDAPEST	19-21 MAY
R10	SPIELBERG	26-28 MAY
R11	IMOLA	02-04 JUN
R12	MONZA	09-11 JUN
R13	MONACO	16-18 JUN
R14	BARCELONA	23-25 JUN
R15	SPA- FRANC.	30 JUN-02 JUL
R16	ZANDVOORT	07-09 JUL
R17	SILVERSTONE	14-16 JUL
R18	MONTREAL	28-30 JUL
R19	LAS VEGAS	01-03 SEP
R20	AUSTIN	15-17 SEP
R21	MEXICO CITY	22-24 SEP
R22	MIAMI	06-08 OCT
R23	SAO PAULO	20-22 OCT

Upon reviewing the scheduled dates, it is noted that races in Italy, Monaco, and Spain are scheduled for June and July. These months may not be ideal due to the likelihood of extreme temperatures. Consequently, this schedule may not be optimal, prompting us to explore alternative solutions that offer a better fit.

Sequential Optimization

In our pursuit of improving the schedule, we proceed to conduct the second optimization which minimizes the total distance by accounting for where the depot is located already from the first step.

Optimal Schedule (with Depot)

1 Schedule calculation. TSP. Distance minimization.

Following our first schedule optimisation, which did not take into account the distance to the Depot, we observed that when adding the emissions due to the journeys from and back to it, they were substantial. To address this, we have incorporated the Depot in the UK into our calculations from the outset of the optimization process. This is the resulting schedule obtained after the implementation of these adjustments:

```
Optimal Schedule (with Depot):
['Silverstone', 'Montreal', 'Las Vegas', 'Austin', 'Mexico City', 'Miami',
'São Paulo', 'Melbourne', 'Singapore', 'Suzuka', 'Baku', 'Yas Marina',
'Lusail', 'Sakhir', 'Jeddah', 'Budapest', 'Spielberg', 'Imola', 'Monza',
'Monaco', 'Barcelona', 'Spa Francorchamps', 'Zandvoort','UK']
```

2 Definition of Means of Transport to Minimize CO_2 Emissions

Having minimized the travel distances and established an optimal schedule with a depot, our next objective is to reduce CO_2 emissions for each trip. We prioritized transportation options based on their carbon emissions, from lowest to highest: boat, truck, and plane. The results obtained are as follows:

- Silverstone => Montreal by boat
- Montreal => Las Vegas by boat
- Las Vegas => Austin by boat
- Austin => Mexico City by boat
- Mexico City => Miami by boat
- Miami => Sao Paulo by truck
- Sao Paulo => Melbourne by plane
- Melbourne => Singapore by boat
- Singapore => Suzuka by boat
- Suzuka => Baku by plane
- Baku => Yas Marina by truck
- Yas Marina => Lusail by boat
- Lusail => Sakhir by boat
- Sakhir => Jeddah by boat
- Jeddah => Budapest by boat
- Budapest => Spielberg by truck
- Spielberg => Imola by truck
- Imola => Monza by truck
- Monza => Monaco by truck
- Monaco => Barcelona by truck
- Barcelona => Spa Francorchamps by truck
- Spa Francorchamps => Zandvoort by truck
- Zandvoort => UK (base) by boat

Given the schedule and the means of transport that will be used, it is now possible to calculate the total distance and total CO_2 emitted in this case:

	Total Distance	Total CO_2 Emission
Official Scedule 2023	157,929 km	218,277 tonnes
Optimal Schedule (no Depot)	85,214 km	41,289 tonnes
Optimal Schedule (with Depot)	71,925 km	35,143 tonnes

Sequential Optimization

The total distance for the Optimal Schedule with Depot is 71,925 km, achieving a **54.46% reduction** compared to the 157,929 km of the Official Schedule 2023, and a **15.59% reduction** compared to the 85,214 km of the Optimal Schedule without Depot. Regarding CO2 emissions, they total 35,143 tonnes, marking an **83.90% reduction** compared to the 218,277 tonnes generated under the Official Schedule, and a **14.89% reduction** compared to the 41,289 tonnes of the Optimal Schedule without Depot.

3 Definition of GP Dates

Once the modes of transportation are determined for each trip, allowing for the estimation of travel duration between cities, the next step is to establish the dates for each Grand Prix. In line with the previous optimization, this process incorporates the following constraints:

- The first race takes place on March 5th,2023.
- Grand Prix events occur on Sunday.
- If travel between cities takes less than 3 days, races are spaced 1 week apart.
- If travel duration falls between 3 and 10 days, races are spaced 2 weeks apart.
- No races are scheduled for January, February, August, and December.

After applying all these conditions, the scheduled dates are as follows:

R1	SILVERSTONE	03-05 MAR
R2	MONTREAL	17-19 MAR
R3	LAS VEGAS	31 MAR - 2 APR
R4	AUSTIN	14-16 APR
R5	MEXICO CITY	21-23 APR
R6	MIAMI	05-07 MAY
R7	SAO PAULO	19-21 MAY
R8	MELBOURNE	26-28 MAY
R9	SINGAPORE	09-11 JUN
R10	SUZUKA	23-25 JUN
R11	BAKU	02-04 JUL
R12	ABU DHABI	07-09 JUL
R13	LUSAIL	14-16 JUL
R14	SAKHIR	21-23 JUL
R15	JEDDAH	28-30 JUL
R16	BUDAPEST	01-03 SEP
R17	SPIELBERG	08-10 SEP
R18	IMOLA	15-17 SEP
R19	MONZA	22-24 SEP
R20	MONACO	29 SEP - 1 OCT
R21	BARCELONA	06-08 OCT
R22	SPA FRANC.	13-15 OCT
R23	ZANDVOORT	20-22 OCT

This configuration, while advantageous in avoiding the hotter months for races in European cities, introduces a new complication: scheduling the Montreal Grand Prix in March, which carries a potential risk of snow. Additionally, races in UAE and Saudi Arabia cities are set for July, a period likely to be extremely hot. Therefore, this schedule may not be entirely suitable, necessitating further exploration of alternative solutions that offer a better fit.

Sequential Optimization

Optimal Contract Schedule

1 Schedule calculation. TSP. Distance minimization.

Following our efforts to improve the F1 calendar, we decided to integrate specific contractual constraints which significantly influence the structuring of the season. The F1 Group has signed long-term agreements with the Bahrain (53 million/race) and Yas Marina (58 million/race) circuits to host the first and last Grand Prix of the season respectively. These races, which generate the highest average audience figures, are key events in terms of visibility and revenue.

After taking account of these contractual constraints in our TSP optimisation model that minimizes total distance, this is the resulting schedule obtained:

```
Optimal Contract Schedule:
[['UK', 'Sakhir', 'Jeddah', 'Budapest', 'Spielberg', 'Imola', 'Monza',
'Monaco', 'Barcelona', 'Spa Francorchamps', 'Zandvoort', 'Silverstone',
'Montreal', 'Las Vegas', 'Austin', 'Mexico City', 'Miami', 'São Paulo',
'Melbourne', 'Singapore', 'Suzuka', 'Baku', 'Lusail', 'Yas Marina', 'UK']
```

2 Definition of Means of Transport to Minimize CO2 Emissions

As before, following the distance minimization process, the next step is to minimize CO_2 emissions for the obtained ordered list of races. The resulting outcomes are the ones that follow:

- UK (base) => Sakhir by boat
- Sakhir => Jeddah by boat
- Jeddah => Budapest by boat
- Budapest => Spielberg by truck
- Spielberg => Imola by truck
- Imola => Monza by truck
- Monza => Monaco by truck
- Monaco => Barcelona by truck
- Barcelona => Spa Francorchamps by truck
- Spa Francorchamps => Zandvoort by truck
- Zandvoort => Silverstone by boat
- Silverstone => Montreal by boat
- Montreal => Las Vegas by boat
- Las Vegas => Austin by boat
- Austin => Mexico City by boat
- Mexico City => Miami by boat
- Miami => Sao Paulo by truck
- Sao Paulo => Melbourne by plane
- Melbourne => Singapore by boat
- Singapore => Suzuka by boat
- Suzuka => Baku by plane
- Baku => Lusail by truck
- Lusail => Yas Marina by boat
- Yas Marina => UK (base) by boat

Given the schedule and the means of transport that will be used, it is now possible to calculate the total distance and total CO_2 emitted in this case:

	Total Distance	Total CO2 Emission
Official Scedule 2023	157,929 km	218,277 tonnes
Optimal Schedule (no Depot)	85,214 km	41,289 tonnes
Optimal Schedule (with Depot)	71,925 km	35,143 tonnes
Optimal Contract Schedule	83,383 km	35,223 tonnes

Sequential Optimization

The total distance of the Optimal Contract Schedule amounts to 83,383 km, which is approximately **47% less** than the 157,929 km of the Official Schedule, about **2% less** than the 85,214 km of the Optimal Schedule without Depot, and about **16% more** than the 71,925 km of the Optimal Schedule with Depot.

Furthermore, the total CO2 emissions associated with this schedule amount to 35,223 tonnes. This represents roughly an **84% reduction** compared to the 218,277 tonnes of the Official Schedule, about **15% less** than the 41,289 tonnes of the Optimal Schedule without Depot, and **nearly the same** emissions as the 35,143 tonnes of the Optimal Schedule with Depot.

3 Definition of GP Dates

In this third step of establishing the dates for each Grand Prix, we apply the same contraints as in the previous optimizations:

- The first race takes place on March 5th,2023.
- Grand Prix events occur on Sunday.
- If travel between cities takes less than 3 days, races are spaced 1 week apart.
- If travel duration falls between 3 and 10 days, races are spaced 2 weeks apart.
- No races are scheduled for January, February, August, and December.

The scheduled dates obtained in this case are the ones that follow:

R1	SAKHIR	03-05 MAR
R2	JEDDAH	10-12 MAR
R3	BUDAPEST	24-26 MAR
R4	SPIELBERG	31 MAR- 2 APR
R5	IMOLA	07-09 APR
R6	MONZA	14-16 APR
R7	MONACO	21-23 APR
R8	BARCELONA	28-30 APR
R9	SPA FRANC.	05-07 JUN
R10	ZANDVOORT	12-14 JUN
R11	SILVERSTONE	19-21 JUN
R12	MONTREAL	02-04 JUL
R13	LAS VEGAS	16-18 JUN
R14	AUSTIN	30 JUN-02 JUL
R15	MEXICO	07-09 JUL
R16	MIAMI	21-23 JUL
R17	SAO PAULO	01-03 SEP
R18	MELBOURNE	08-10 SEP
R19	SINGAPORE	22-24 SEP
R20	SUZUKA	06-08 OCT
R21	BAKU	13-15 OCT
R22	LUSAIL	20-22 OCT
R23	YAS MARINA	27-29 OCT

Unlike previous iterations, this schedule appears well-suited to existing contractual constraints and weather conditions, with races thoughtfully spaced to avoid extreme climates. This strategic planning aims to ensure safer and more predictable competitions. Additionally, as the total CO2 emissions for this optimal schedule approach the lowest figures achieved in prior optimizations, we believe this may be the best option among all those analyzed.

Extension

Cost Estimation

In our comprehensive analysis of transportation solutions, we decided to incorporate cost metrics in dollars ($) for each option. This approach is crucial as it provides a holistic assessment of total expenses, including direct costs like the price per mode of transport, as well as indirect costs such as environmental impact. By using consistent metrics, we enable straightforward comparisons between different solutions. This helps stakeholders make informed decisions, optimizing both economic and environmental outcomes.

First, we focused on the direct costs of different transportation modes.

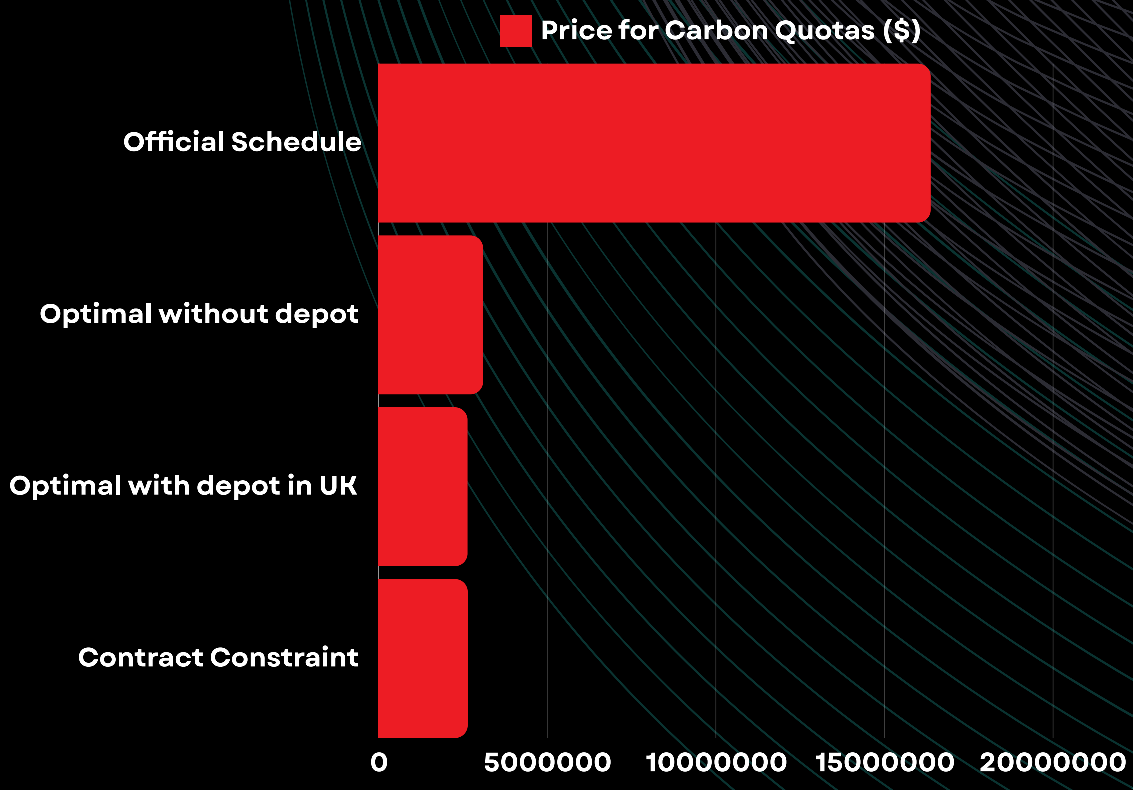
The table below summarizes the costs associated with transporting the required 1500 tonnes, based on different modes of transportation for each solution:

	TRUCK	PLANE	BOAT	TOTAL
Price of Tranportation	600$/km	285$/km	2.1$/km	
Official Schedule	20,754 km	137,174 km	0 km	51,547,155 $
Optimal Schedule (No Depot)	14,823 km	23,221 km	47,169 km	15,611,287$
Optimal Schedule With Depot	14,823 km	20,406 km	36,694 km	14,786,877 $
Contract Schedule	14,613 km	20,406 km	48,362 km	14,685,529 $

Extension

Cost Estimation

For several years now, the European Union has been trying to set up a carbon quota market, which is supposed to internalize the price of emissions. Far from perfect, the European carbon market remains one of the most efficient in the world. We decided to see what the financial surplus would be if Formula 1 had to pay for the greenhouse gas emissions it produces. We multiply the number of tonnes of carbon emitted by Formula 1 logistics by the price of a tonne of carbon in Europe (around $75/tonne). This calculation allows us to take into account the negative externalities of emissions in the price of logistics. The numbers below show that if Formula 1 had to pay for their emission, they would pay $16,370,786.2 with the current calendar. However this cost can be decreased to $2,635,735.5 with the optimized path.



Comparison of Results

Scenario	Total Distance	Total CO2 Emission	Total Cost
Official Scedule 2023	157,929 km	218,277 tonnes	51,547,155 $
Optimal Schedule (no Depot)	85,214 km	41,289 tonnes	15,611,287 $
Optimal Schedule (with Depot)	71,925 km	35,143 tonnes	14,786,877 $
Optimal Contract Schedule	83,383 km	35,223 tonnes	14,685,529 $

To conclude this first part, our analysis reveals that optimizing the F1 schedule can lead to significant reductions in both emissions and costs. By comparing the official 2023 schedule with our proposed optimized schedules, we can see clear trade-offs and advantages:

The official 2023 schedule results in high total distances, CO2 emissions, and costs. In contrast, the optimized schedules demonstrate that strategic planning and efficient logistics can drastically cut these metrics. The optimal schedules, whether with or without considering the depot from the first steps, reduce the total distance traveled by nearly half, resulting in substantial decrease in CO2 emissions and also overall transportation costs.

Moreover, the optimal contract schedule, which includes respecting existing contracts as a constraint, still achieves a highly efficient solution. This schedule's performance is close to the depot optimization, and aligns well with the practical economic realities of F1 operations.

These findings underscore the potential for significant environmental and economic improvements through optimized scheduling. By adopting such strategies, F1 can reduce its carbon footprint and operational expenses, setting a precedent for sustainable logistics in the sporting world.

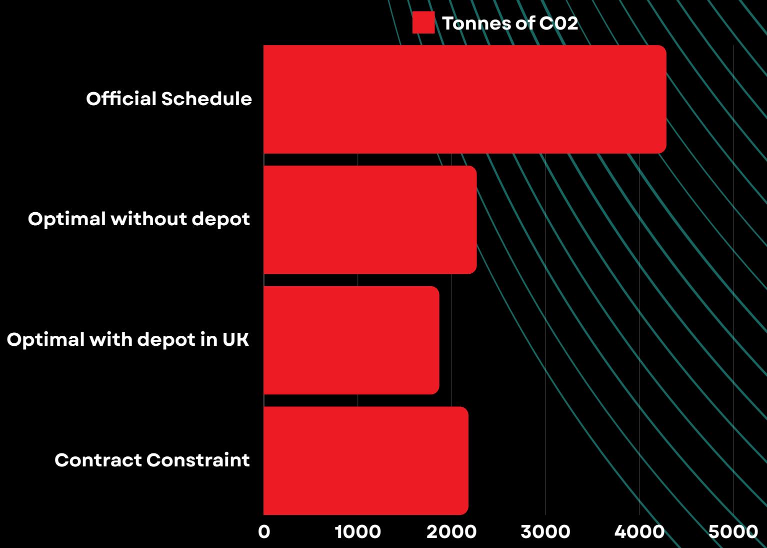
Extension

Private Jet

In the Formula 1 Championship Impact Report, it is mentioned that 'business travel', defined as all individual transport by air and land as well as the impact of hotels for all F1 teams and partners, represents 27% of total emissions.

To assess the impact of our schedule optimisations on this category of emissions, we used our distance matrix in kilometers. We multiplied these distances by an emission factor of 3 kg of CO_2 per kilometer traveled by private jet. Since each team has a jet and there are 10 teams in total, we applied an additional multiplier of 10.

We then calculated the total emissions associated with each journey for each calendar variant considered. This calculation allows us to state that our schedule optimisation solutions significantly reduce not only the logistical impact but also the emissions associated with individual team journeys.



Numbers always consider the emission of going back to the depot

In practice, this translates into a significant reduction in emissions: for example, compared to the official calendar, the optimal contract schedule could reduce emissions from private jet travel by 50%. This integrated approach demonstrates the effectiveness of our optimisation strategies in reducing the overall carbon footprint of the Formula 1 championship.

Extension

2025 Schedule

Round	Dates	Country	Circuit	Round	Dates	Country	Circuit
R1	14-16 MAR	AUSTRALIA	MELBOURNE	R13	25-27 JUL	BELGIUM	SPA
R2	21-23 MAR	CHINA	SHANGHAI	R14	01-03 AUG	HUNGARY	BUDAPEST
R3	04-06 APR	JAPAN	SUZUKA	R15	29-31 AUG	NETHERLANDS	ZANDVOORT
R4	11-13 APR	BAHRAIN	SAKHIR	R16	05-07 SEP	ITALY	MONZA
R5	18-20 APR	SAUDI ARABIA	JEDDAH	R17	19-21 SEP	AZERBAIJAN	BAKU
R6	02-04 MAY	USA	MIAMI	R18	03-05 OCT	SINGAPORE	SINGAPORE
R7	16-18 MAY	ITALY	IMOLA	R19	17-19 OCT	USA	AUSTIN
R8	23-25 MAY	MONACO	MONACO	R20	24-26 OCT	MEXICO	MEXICO CITY
R9	30 MAY-01 JUN	SPAIN	BARCELONA	R21	07-09 NOV	BRAZIL	SÃO PAULO
R10	13-15 JUN	CANADA	MONTREAL	R22	20-22 NOV	USA	LAS VEGAS (*SAT RACE)
R11	27-29 JUN	AUSTRIA	SPIELBERG	R23	28-30 NOV	QATAR	LUSAIL
R12	04-06 JUL	UNITED KINGDOM	SILVERSTONE	R24	05-07 DEC	ABU DHABI	YAS MARINA

Considering the potential for future impact, we decided it would be interesting to explore how the Official Schedule for the 2025 F1 season could be optimized.

The table to the left is the official calendar that has been put online by the F1.

This schedule mostly consists of the same cities as for the 2023 season, except from the addition of a race in Shanghai and a different starting point, Melbourne.

After following the same steps as in previous optimizations, the optimal schedule for the 2025 season, which now incorporates Shanghai and the different transportation options (plane, ship, truck, and train), is as follows:

Round	City	Dates
R1	MELBOURNE	14-16 MAR
R2	SINGAPORE	28-30 MAR
R3	SHANGHAI	11-13 APR
R4	SUZUKA	18-20 APR
R5	LAS VEGAS	25-27 APR
R6	AUSTIN	09-11 MAY
R7	MEXICO CITY	16-18 MAY
R8	SAO PAULO	30 MAY - 01 JUN
R9	MIAMI	06-08 JUN
R10	MONTREAL	20-22 JUN
R11	SILVERSTONE	04-06 JUL
R12	ZANDVOORT	11-13 JUL
R13	SPA	18-20 JUL
R14	BARCELONA	25-27 JUL
R15	MONACO	05-07 SEP
R16	MONZA	12-14 SEP
R17	IMOLA	19-21 SEP
R18	SPIELBERG	26-28 SEP
R19	BUDAPEST	03-05 OCT
R20	BAKU	10-12 OCT
R21	JEDDAH	17-19 OCT
R22	SAKHIR	24-26 OCT
R23	LUSAIL	31 OCT - 02 NOV
R24	ABU DHABI	07-09 NOV

Extension

2025 schedule

Travel back and to the Depot - Traveling from Abu Dhabi back to the UK by boat is feasible, with the journey taking only a few days and offering the advantage of significantly reducing CO2 emissions. However, the situation is more complex for the journey from the UK to Melbourne. Opting for the boat would take 38 days, which can be somewhat compensated by the fact that the recommended schedule is 28 days shorter than the official one. Nevertheless, it remains a major hindrance. On the other hand, opting for the plane would take less than a day but would result in substantially higher CO2 emissions. Nonetheless, in both cases, substantial reductions in CO2 emissions are achieved, as shown in the table below.

Replace truck by train in Europe - The train is a means of transporting goods that is less polluting than trucks. Indeed trains only emit 24 grams of CO2 per tonne-km against 137 for heavy goods vehicles. However, rail is poorly developed throughout the world. Only in Europe did this alternative make sense in our analysis. This is why we calculated the reduction in emissions that would result from transporting logistics by train rather than by truck throughout Europe. To do this, we assumed that the train would cover the same distances as truck, but we multiplied these distances by the train's pollution coefficient. This gives us the train-related emissions and enables us to calculate the reduction in greenhouse gas emissions resulting from such a change. We found that replacing trucks with trains reduces emissions in Europe from 797 tonnes of CO2 to 140 tonnes, representing an 82% decrease.

Scenario	Total CO2 Emissions	Emissions Improvement	Financial costs
Official Schedule 2025	207855 tonnes	0%	41,817,706$
Recommended Schedule (plane to Melbourne)	63878 tonnes	69.3%	21,323,678$
Recommended Schedule (plane to Melbourne & train in Europe)	63220 tonnes	69.6%	19,285,437$
Recommended Schedule (boat to Melbourne)	29249 tonnes	85.9%	16,550,641$
Recommended Schedule (boat to Melbourne & train in Europe)	28591 tonnes	86.2%	14,512,400$

Extension

2025 schedule

Comparison of private jets emissions

By reducing the total distance traveled, the schedule we recommend also leads to less emissions from the private jets used by teams as seen below:

Scenario	Total CO_2 Emissions (private jets)	Improvement
Official Schedule 2025	4108 tonnes	0%
Recommended schedule	2321 tonnes	44%

How different is the recommended schedule compared to the original ?

The 2025 Optimal Schedule significantly differs from the Official Schedule. It is 28 days shorter, indicating a more compact season, although this compression is not essential. There are 152 positional changes in the race order, with the sequence altered by 55% compared to the maximum possible sequence change, demonstrating substantial reordering.

On average, each race date in the optimal schedule differs from the original schedule by 10 days, with changes for individual race dates ranging from a median of 7 days to a maximum of 28 days. Only 3 race dates remain unchanged. For specific cities, the corresponding race dates differ by an average of 80 days, with changes ranging from a median of 52 days to a maximum of 209 days, and only 2 dates remaining unchanged.

These major differences between both schedules would entail complex challenges for all parties involved (teams, organizers, broadcasters, fans, etc.). Therefore, transitioning from one schedule to the other would require substantial adaptation, renegotiation, and investment. However, this effort is justified as the substantial reductions in CO_2 emissions enabled by our optimal schedule might prove indispensable in the context of the F1's objective of achieving net-zero emissions.

Managerial Recommendations

- **Approach Carbon Neutrality by 2030 by Reducing Travel Distances and Opting for More Efficient Transportation**

The consecutive races across continents in the different F1 official schedules are highly inefficient regarding carbon emissions. By focusing on reducing the distances between consecutive Grand Prix and considering the most effiicient and feasible modes of transportation used for these journeys, the impact could be substantial, potentially reducing CO2 emissions by more than 80%. This would help achieve F1 commitment of becoming carbon neutral by 2030.

- **Increase Profitability while becoming more Sustainable**

By reducing distances and CO2 emissions, the impact would be significant not only for the environment and society but also economically for the company. Shorter travel distances lead to lower fuel costs and a reduction in the general resources needed. These savings could directly enhance profitability by decreasing operational expenses.

- **2025 Schedule Recommendation**

We strongly recommend that Formula 1 adopt the proposed calendar for the 2025 Schedule. Implementing this schedule could lead to a reduction in CO2 emissions by over 85%. The choice of transportation from the depot to Melbourne is left to their choice. If reducing CO2 emissions is a priority, we highly recommend selecting the boat option. However, if a 38-day journey is deemed too lengthy, flying may be the better choice. Regardless of the transport method chosen, the impact will be substantial and will help the organization advance toward its strategic goals.

Appendix

Calculations

1 CO2 Matrices

Air Cargo (Planes): The emission factor for air cargo is 1036 grams of CO2 per tonne-kilometer. For transporting 1500 tonnes, the calculation is:
1036 grams CO2/t-km × 1500 tonnes = 1,554,000 grams CO2/km
Converting grams to kilograms:
- 1,554,000 grams CO2/km = **1554 kg CO2/km**

Heavy Goods Vehicles (Trucks): The emission factor for trucks is 137 grams of CO2 per tonne-kilometer. For transporting 1500 tonnes, the calculation is:
137 grams CO2/t-km × 1500 tonnes = 205,500 grams CO2/km
Converting grams to kilograms:
- 205,500 grams CO2/km = **205.5 kg CO2/km**

Maritime Shipping (Ships): The emission factor for ships is 7 grams of CO2 per tonne-kilometer. For transporting 1500 tonnes, the calculation is:
7 grams CO2/t-km × 1500 tonnes = 10,500 grams CO2/km
Converting grams to kilograms:
- 10,500 grams CO2/km = **10.5 kg CO2/km**

Rail Shipping (Train): The emission factor for ships is 24 grams of CO2 per tonne-kilometer. For transporting 1500 tonnes, the calculation is:
24 grams CO2/t-km × 1500 tonnes = 36,000 grams CO2/km
Converting grams to kilograms:
- 36,000 grams CO2/km = **36 kg CO2/km**

By using these consistent metrics, we ensured our CO2 emission calculations are accurate and based on standardized data.

Appendix

Calculations

2 Transportation costs for 2023

Costs per mode of transport:
- Truck: $0.4/t-km
- Boat: $0,0014/t-km
- Plane: $0,19/t-km
- Train: $0,045/t-km

Thus, to transport the 1500 tons per km needed using different modes of transport, here are the estimated costs:
- Truck: $0.4 * 1500 t = $600 per km
- Boat: $0.0014 * 1500 t = $2.1 per km
- Plane: $0.19 * 1500 t = $285 per km
- Truck: $0,045 * 1500 t = $67.5 per km

Here are the calculations for the different solutions:

1. **Official Schedule (2023)**

- Total distance: 157,928.56 km
    - Truck: 20,754.02 km
    - Plane: 137,174.54 km

Cost breakdown:
- Truck: 20,754.02 km * $600 = $12,452,412.00
- Plane: 137,174.54 km * $285 = $39,094,743.90
- **Total Cost. $51,547,155.90**

2. Optimal Schedule (No Depot)

- Total distance: 85,214.25 km
    - Boat: 47,169.00 km
    - Truck: 14,823.29 km
    - Plane: 23,221.96 km

Cost Breakdown:
- Boat: 47,169.00 km * $2.1 = $99,054.90
- Truck: 14,823.29 km * $600 = $8,893,974.00
- Plane: 23,221.96 km * $285 = $6,618,258.60
- **Total Cost. $15,611,287.50**

Appendix

Calculations

2 Transportation costs for 2023

3. Optimal Schedule (With Depot)

- Total distance: 71,924.59 km
  - Boat: 36,694.83 km
  - Truck: 14,823.29 km
  - Plane: 20,406.47 km

Cost Breakdown:
- Boat: 36,694.83 km * $2.1 = $77,059.14
- Truck: 14,823.29 km * $600 = $8,893,974.00
- Plane: 20,406.47 km * $285 = $5,815,843.95
- **Total Cost. $14,786,877.09**

4. Contract Schedule

- Total distance: 83,382.51 km
  - Boat: 48,362.50 km
  - Truck: 14,613.54 km
  - Plane: 20,406.47 km

Cost Breakdown:
- Boat: 48,362.50 km * $2.1 = $101,561.25
- Truck: 14,613.54 km * $600 = $8,768,124.00
- Plane: 20,406.47 km * $285 = $5,815,843.95
- **Total Cost. $14,685,529.20**

Appendix

Calculations

3 Transportation costs for 2025

1. Official 2025 Schedule

- Total distance: 136,949.31 km
  - Truck: 7319.80 km
  - Plane: 131,318.69 km

Cost Breakdown:

- Truck: 7319.80 km * $600 = $4,391,880.00
- Plane: 131,318.69 km * $285 = $37,425,826.60
- **Total Cost. $41,817,706.60**

2. 2025 Recommended Schedule (plane to Melbourne)

- Total distance: 86,391.84 km
  - Boat: 33,787.75 km
  - Truck: 19,874.79 km
  - Plane: 32,729.30 km

Cost Breakdown:

- Boat: 33,787.75 km * $2.1 = $70,954.28
- Truck: 19,874.79 km * $600 = $11,924,874.00
- Plane: 32,729.30 km * $285 = $9,327,850.50
- **Total Cost. $21,323,678.80**

3. 2025 Recommended Schedule (plane to Melbourne & train in Europe)

- Total distance: 86,391.84 km
  - Boat: 33,369.67 km
  - Truck: 15,995.76 km
  - Plane: 32,729.30 km
  - Train: 4,297.11 km

Cost Breakdown:

- Boat: 33,369.67 km * $2.1 = $70,076.31
- Truck: 15,995.76 km * $600 = $9,597,456.00
- Plane: 32,729.30 km * $285 = $9,327,850.50
- Train: 4,297.11 km * $67.5 = $290,054.93
- **Total Cost. $19,285,437.7**

Appendix

Calculations

3 Transportation costs for 2025

4. 2025 Recommended Schedule (boat to Melbourne)

- Total distance: 96,560.22 km
  - Boat: 60,903.43 km
  - Truck: 19,874.79 km
  - Plane: 15,782.00 km

Cost Breakdown:

- Boat: 60,903.43 km * $2.1 = $127,897.20
- Truck: 19,874.79 km * $600 = $11,924,874.00
- Plane: 15,782.00 km * $285 = $4,497,870.00
- **Total Cost. $16,550,641.2**

5. 2025 Recommended Schedule (boat to Melbourne & train in Europe)

- Total distance: 96,560.22 km
  - Boat: 60,485.35 km
  - Truck: 15,995.76 km
  - Plane: 15,782.00 km
  - Train: 4,297.11 km

Cost Breakdown:

- Boat: 60,485.35 * $2.1 = $127,019.26
- Truck: 15,995.76 km * $600 = $9,597,456.00
- Plane: 15,782.00 km * $285 = $4,497,870.00
- Train: 4,297.11 km * $67.5 = $290,054.93
- **Total Cost. $14,512,400.20**