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Application of Operations Research for Lap Time Optimization in Formula 1 Racing

Lavanya Choudhury
choudhurylavanya@gmail.com
Narsee Monjee Institute of Management Studies, Mumbai, Maharashtra

Krishnam Pachiesia
krishnam.pachiesia282@nmims.edu.in
Narsee Monjee Institute of Management Studies, Mumbai, Maharashtra

Manav Rohira
manav.rohira109@nmims.edu.in
Narsee Monjee Institute of Management Studies, Mumbai, Maharashtra

Manavv Sarrdana
manavv.sarrdana047@nmims.edu.in
Narsee Monjee Institute of Management Studies, Mumbai, Maharashtra

Mokshil Mehta
mokshil.mehta169@nmims.edu.in
Narsee Monjee Institute of Management Studies, Mumbai, Maharashtra

ABSTRACT

Our research paper is based on lap time optimization of an F1 car in a race. We have achieved this with the use of various Operations Research techniques. In order to explain how the overall lap time is forecasted and optimized, the Monte Carlo Simulation method has been used. The Hungarian Assignment Problem helped us determine the most efficient allocation of a pit crew in a pit stop in a race to get the lowest possible pit stop time. Game Theory is used in order to understand the mind-set of a driver driving wheel-to-wheel on every chicane. We have also dealt with the Decision Theory to gain insights on the choice of tyres made by teams on a race weekend. Many smaller variables, such as lap time variations, affect the outcome of a race. As a result, if a potentially winning strategy is to be devised, these occurrences and influences should be modelled within the race simulation. Using these OR techniques we have formulated a way in which we can optimise the race time from different race situations.

Keywords— *Formula-1, Lap-time Optimization, Monte Carlo Simulation, Hungarian Assignment Method, Game Theory, Decision Theory*

1. INTRODUCTION

Formula One is the most noteworthy class of global auto dashing for single-seater recipe hustling vehicles authorized by the Fédération Internationale de l'Automobile (FIA). The World Drivers' Championship, which turned into the FIA. Formula One World Championship in 1981, has been one of the chief types of hustling throughout the planet since its debut season in 1950. The word Formula in the name alludes to the arrangement of rules to which every one of members' vehicles should adjust. A Formula One season consists of a series of races, known as Grand Prix, which take place worldwide on both purpose-built circuits and closed public roads.

The reason we chose this topic is that, in the field of Operations Research, although it had a lot of potentials, it was almost untouched. Coming to the Operations Research techniques that helped us with achieving our objective, which is to minimize and optimize lap time, we have chosen different segments of F1 racing and applied various techniques to them. Choosing the right tyre is done by way of Decision Making. The probability of how a Formula 1 driver would react to situations on track has been measured using the concept of Game Theory.

The quantitative aspects that affect lap timings are calculated using The Monte Carlo Simulation. Finally, arguably, one of the most important factors is the job allocation during pit-stops, which can be considered as an assignment problem, which has been dealt with using the Hungarian Assignment Method.

These Operations Research techniques not only consider the quantitative factors but also take into consideration the qualitative factors. We were able to analyze various segments involved on and off the track, and potentially contribute some of our analysis and research to the vast world of Formula 1 Racing.

Our topic for this research paper is mainly to optimize lap timings during the race. It is a simple formula, lesser time spent on pit stops equals more chances of winning. But, in this paper, we don't only focus on pit stop timings. This is our attempt to shine a light on some of the decisions that take place behind the screens and how they are relevant to lap time optimization. The choice of selecting the right tyre is a crucial one. Mishaps turn from potentials to realities real quick on a track and the root cause for a lot of crashes can be the tyres. There are several factors to be kept in mind and they have been elaborated on further in the paper.

2. LITERATURE REVIEW

The motivation behind this research paper comes from a place of curiosity and great potential. We believe that using Operations Research, we can come up with viable solutions to reduce the lap time in F1 racing. The Red Bull team holds the world record for the fastest pit stop, with a time of 1.92 seconds. An F1 team must be prepared to develop and execute a flexible pit-stop strategy throughout a Grand Prix. The observations of (Stavropoulos, 2018) and (Wieczorek, 2019) on the functionality of F1 races and the tasks of logistics processes were mostly backed by international online sources, as well as domestic literature. The pit stop in Formula 1 is seen as a model illustration of how a multi-professional team can work together as a single unit to complete a complicated task under extreme time constraints with minimum error. Using data from these pit stops, the research of Neil Martin (Martin, 2014) and (R.Catchpole, 2007) discusses how patient care might be made safer. The demand for teamwork and safety skills drew comparisons to the aviation industry, which has a 20-year track record of successfully training in these skills. The limit is 110 gallons but the capacity filled varies from track to track and also depends on the weather. A lot of thought goes into calculating the amount of fuel a car can carry as well as how much weight it can hold. Red Bull, an absolute behemoth in the motorsport sphere. Before the hybrid era, they had been the constructors' champions for four years in a row and had completely dominated the sport. In the (Mello, 2005) article, the disadvantages of the methodology are explored, along with an explanation of how to reduce them, as well as a description of the possible consequences of employing the Condorcet method rather than the Borda method. The goal of (Singh, 2021) and (Spurgeon, 2008) study was to translate knowledge about human factors and task organization that is embedded in one of the most thrilling maintenance procedures, the pit stop. The findings are an organized collection of suggestions that cover the most important factors to consider while determining proper maintenance procedures. The guidelines should be evaluated in a variety of working environments to ensure that they are applicable outside of the racing world. In (Iyengar, Roshni Iyengar, 2017), Formula One is the world's most prestigious motorsports championship. A massive amount of logistics work is required to keep the sport running. Every race week all the bolts, spare parts, the car itself, and things as small as the chairs for the restaurant need to reach different locations. The teams use 3 modes of transport- air, road, transport to make sure everything enters the paddock so by Thursday practice and track walk everything has assembled. Optimizing tyre usage is critical when driving an F1 car. (Iyengar, Roshni Iyengar, 2017) Decisions are made based on the effectiveness of the pit stop and the driver's ability to utilize the tyre to his advantage. An analytical evaluation is performed when choosing the combination of tyres and the number of pit stops planned in a race. The above were valuable contributions in this field but the area of research lacks information about the different methodologies and mathematical formulations of their views. We have tried to contribute to this field of study by incorporating some appropriate OR techniques which have been discussed further in the paper.

3. METHODOLOGY AND DATA

1. Monte Carlo Simulation Method

The first simulation step in every lap l is to calculate the expected lap times *"tlap"* of the drivers.
To obtain them, the simulation adds up several different time parts in a lap time model. *"tbase"* is the lap time that the fastest car-driver combination can theoretically achieve in the race, that is when the tyres are fresh and the car has almost no fuel onboard. It consequently considers the attributes of the race track. To this premise are added: "ttyre" for the impact of tyre debasement (subject to tyre age "atyre" and compound "ctyre"), "tfuel" for the time lost because of the fuel mass that is conveyed in the vehicle, "tcar" and "tdriver" for the vehicle and driver capacities, "tgrid" for the time that is lost at the race start (reliant upon framework position "pg") and "tpit, in-lap/out-lap" for the time that is lost in refueling breaks.

$$tlap(l) = tbase + ttyre(atyre, ctyre) + tfuel(l) + tcar + tdriver + tgrid(l, pg) + tpit,in\text{-}lap/out\text{-}lap(l)$$

Consecutive lap times of a driver are summed up to obtain his race times trace at the end of every lap

$$trace(l) = \sum_{i=1}^{l} tlap(i)$$

2. Game Theory Model of F1

John Nash showed that a non-agreeable n-player game, in which every player has a limited arrangement of potential procedures, should have something like one mark of harmony. This balance is a state where every player's decision of technique can't be improved, given each player's decision of system. In game-hypothetical language, every player's result is boosted, given every player's decision of technique.
In formal terms, there must be an n-tuple of strategies $\sigma = (\sigma 1,...,\sigma n)$ in which the pay-off for each player, vi, is maximized:
$vi(\sigma) = \max vi\ (\sigma 1,...,\sigma n)$, for $i = 1,...,n$
Where the maximum is taken over all the player-i strategies, σi.
The arrangement of methodologies took on by the groups at every Grand Prix ought to have somewhere around one such territory of Nash balance, (regardless of whether the contenders are fit for tracking down that ideal state). However, it's possible to define a simple and realistic scenario that, at first sight, undermines Nash equilibrium.

3. Hungarian Assignment Method

For the designation of occupations to different specialists, we have decided on HAM to track down the most proficient task which will advance lap time.

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The Hungarian Method is a calculation created by Harold Kuhn to tackle task issues in polynomial time. We have used this method in the below example to show how it can contribute to our area of research.

Objective:
To show that this method is suitable for the assignment of jobs to workers in F1 racing. It can result in a more efficient allocation of work and minimization of pit-stop time.

Assumption:
For the below example, although the timings are well within the range of the actual pit-stops timings, they have been assigned randomly.

Assignment Problem Example

		Jobs (Time in Seconds)			
		A	B	C	D
Workers	1	0.8	0.7	1.2	1.4
	2	0.5	0.7	0.9	0.6
	3	0.5	0.6	0.5	0.3
	4	0.8	0.6	0.4	0.7

Step 1
Number of Rows = Number of Columns
Balanced

Step 2
Row Minima

	A	B	C	D
1	0.8	0	1.2	1.4
2	0	0.2	0.4	0.1
3	0.2	0.3	0.2	0
4	0.4	0.2	0	0.3

Step 3
Column Minima

	A	B	C	D
1	0.3	0.1	0.8	1.1
2	0	0.1	0.5	0.3
3	0	0	0.1	0
4	0.3	0	0	0.4

Number of Allocations=Order of AP

Optimal

Step 4

Assignments		
Worker	Job	Time
1	B	0.7
2	A	0.5
3	D	0.3
4	C	0.4
Total Pit Stop Time		1.9 Seconds

Note: Red-Bull Racing holds the current world record for the fastest pit stop in F1 history, with a 1.82 second stop performed at the 2019 Brazilian Grand Prix on Max Verstappen.

Job A- Lifting the Car and Putting the Car Down
Job B- Wheel In
Job C- Wheel Out
Job D- Gun Man

Analysis and Findings

1. Analysis of the Monte Carlo Method to Consider Probabilistic Effects in a Race Simulation
Applying the best racing strategy is the decisive factor in obtaining the best results in a racing competition. This mainly involves

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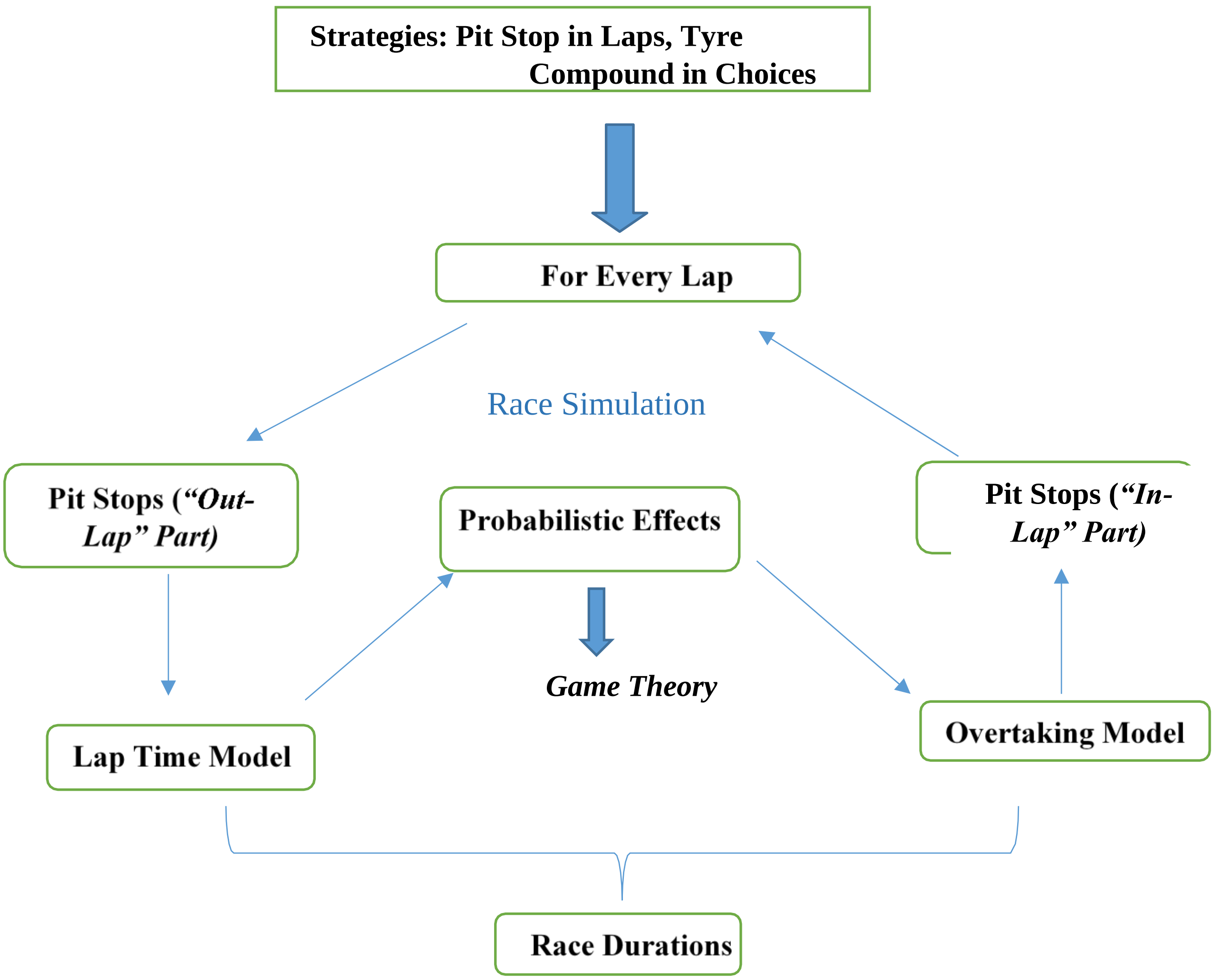
the perfect pit stop time and the selection of the best tyre compound. Strategy engineers use game simulations to evaluate the impact of different strategic decisions (for example, early or late pit stops) on the results of the game before and during the game. In any case, truly, races seldom work out as expected and are regularly dictated by arbitrary occasions, for example, mishaps that lead to the wellbeing vehicle stage. Additionally, race progress will be affected by many lesser odds, such as changes in lap time. Therefore, if a real game is to be simulated and a solid game strategy is to be determined, these events and effects must be modeled in the game simulation.

The outcomes exhibited the legitimacy of the model and showed how the Monte Carlo Simulation can evaluate the strength of the opposition technique. Understanding robustness can improve the basis for strategy engineers to reasonably determine competing strategies. Running simulation is used to simulate and compare the effects of different running strategies.



2. Why is Game Theory Used?

Monte Carlo simulation can give you a probable outcome of a race. In any case, this re-enactment can't consider cooperation between various gatherings. Computer scientists and mathematicians are increasingly interested in resolving problems in situations where multiple self-interested parties interact. To act optimally in such a situation, each player must take into account how the other players are likely to act. Game hypothesis concentrates on how this ought to be done, and it gives different arrangement ideas which endorse how players should act when the activities of different players influence their game or procedure. Thusly, Game hypothesis programming will audit these ideas, just as operationalize them by giving calculations to process the arrangements.

The Above figure has only a 2 driver model, for a race, there will be 24

Suppose that a Ferrari is ahead of a Mercedes in the early laps of a race, but the Mercedes has a pace advantage. Assume, nonetheless, that the speed delta between the vehicles is not exactly the base edge for a non-no likelihood of the Mercedes overwhelming the Ferrari.

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Assume that because of streamlined impedance from the wake of the vehicle ahead, the Mercedes can't follow nearer than 1.5 seconds behind the Ferrari, and assume that tire corruption is adequately low that new tires give a 1-lap undercut worth under 1 second. Regardless of whether Mercedes pit first, Ferrari can react the following lap, and (expecting a blunder-free stop) will arise still leading the pack. In case Mercedes is to beat Ferrari they should utilize an alternate procedure.

Presently, if the Mercedes changes to a 2-stop system, it will be out of sync with the Ferrari, will want to circle at its actual speed, and will want to beat the Ferrari if the Scuderia stay on a 1-stop. (Assuming that there are traffic-free gaps into which the Ferrari can pit, without being delayed by other competitors).

However, if Ferrari anticipates this, and plans a 2-stop strategy, it will still win the race. If both cars are on the 2-stop strategy, Mercedes cannot utilize its superior pace. In any case, notwithstanding, if Mercedes expects that, it can dominate the race by adhering to the first 1-stop strategy...which Ferrari, once more, can take off by staying with the 1-stop. Etc, endlessly. There is no Nash balance here. Every conceivable mix of methodologies is with the end goal that somewhere around one contender can work on their result by changing the system if the other contender's methodology stays fixed.

The issue here is that the techniques considered are named 'pure' methodologies in game-hypothetical terms. Nash's hypothesis relates not to unadulterated methodologies, but rather to probabilistic blends of pure techniques, called 'blended' procedures. If there are two possible pure strategies, A and B, a mixed strategy is one in which, for example, you resolve to follow strategy-A 30% of the time, and strategy-B 70% of the time. You should likewise utilize an arbitrary number generator to implement the probabilistic split.

A blended methodology, then, at that point, is a somewhat conceptual thing, and not something which addresses human key reasoning. Individuals frequently have emergency courses of action, elective procedures that they will embrace if certain occasions happen, however they once in a while outline their unique system as far as probabilistic blends. As far as the Formula 1 procedure situation characterized above, there is a territory of Nash balance: if Ferrari and Mercedes both take on the blended methodology of seeking after a 1-stop with half likelihood and a 2-stop with half likelihood, then, at that point, neither one of the contenders has a blended technique which offers an improvement as far as their normal result.

3. Decision Theory

Choice hypothesis is principally worried about aiding individuals and associations in deciding. It gives a significant calculated structure to a significant dynamic. The dynamic alludes to the choice of a demonstration from among different other options, the one which is decided to be awesome under given conditions. The factual choice hypothesis attempts to uncover the sensible design of the issue into elective activity, conditions of nature, potential results, and possible settlements from each such result. Sometimes choices are logical and they require the information. The supervisors use this quantitative information for taking the choices and discover the better choice.

Rules of F1 and Tyre Information

The selection of tyres is called 'A Dark Art'. In formula one, every track condition requires different types of tyres. These tyres are only 10% natural rubber and apart from that it's made of synthetic compounds and reinforcing filler. They have an average temperature of 80 degrees. Unlike natural tyres, these are filled with nitrogen. FIA has imposed a few rules for the selection and use of tyres. Each team gets 13 sets of tyres every race weekend out of which 3 seats are reserved for the main race. The other 10 sets can be used in practice and qualifying. On the main race, a minimum of 1 pit stop is required and at least 2 different types of compound tyres should be used in the race. A formula one Grand Prix occurs throughout the year in gaps of a few weeks and sometimes back to back for a couple of weeks. Excluding the testing race, there are 22 grand Prix initially scheduled this year. Every grand Prix is hosted at a different location and every location has a different type of track and weather condition. Ranging from tyres for wet conditions to specifically having tyres of street circuits, formula one has a detailed guideline of which tyres can be allowed in which type of conditions. After that, it's up to the teams to make the best out of the available options. Starting with two major segregation i.e. wet conditions and dry conditions. For wet conditions, each team can either use 'wet tyre' or 'intermediate tyre'; these wet condition tyres are designed to displace up to 65 liters of water per second. On the other hand, for dry races teams have an option to select from another 5 options i.e. 'hyper soft', 'super soft', and 'soft', 'medium', 'hard'. For the dry races, the harder the tyre gets the more durable it gets but the average lap time of the racer reduces.

A rise in temperatures by even 1° C can result in shortening of tyres life by 3-5 laps. Cooler weather conditions mean tyres would last longer than usual. It's also dependent on whether the drivers are running in cooler airs or is stuck behind some other car. An attacking driver means he'll lose the tyres sooner than later, also the lock-ups made by the drivers if they ran wide into the corner. It's all to the fact that how good a driver is in nursing his tyres.

Characteristics of the Tyres

Wet: The full wet tyres are the most effective for heavy rain. These tires can empty 85 liters of water each second per tire at 300kph: when it rains vigorously, permeability instead of hold causes issues. The profile has been intended to build protection from aquaplaning, which gives the tire more grasp in a weighty downpour. The breadth of the full wet tire is 10mm more extensive than the smooth tire.

Intermediate: The intermediates are the most versatile of the rain tyres. They can be utilized on a wet track with no standing water, just as a drying surface. This tire clears 30 liters of water each second per tire at 300kph. The compound has been intended to grow the functioning reach, as seen at various races last year, ensuring a wide hybrid window both with the slicks and the full wets.

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Hyper Soft: the fastest compound that Pirelli has ever made. This tire is appropriate for all circuits that request undeniable degrees of mechanical hold, however, the compromise for this additional speed and attachment is an impressively more limited life expectancy than different tires in the reach. It's anything but a passing tire, however, it comes nearest.

Soft: works well on tight and twisty circuits. It has a quick warm-up and immense maximized operation, yet the opposite side of this is it's moderately restricted generally speaking life. Nonetheless, the further developed consistency of the current year's mixtures should imply that the milder elastic is prepared to do more adaptable use and less inclined to overheating.

Medium: strikes a very good balance between performance and durability, with the accent on performance. A truly versatile tire can be utilized as the mildest compound at a high-seriousness track just as the hardest compound at a low-seriousness track or road circuit. It is one of the most commonly used compounds of all.

Hard: a very versatile compound that sits at the harder end of the spectrum. It comes into its own on circuits that tend towards high speeds, temperatures, and energy loadings. This tire has shown an adequate working reach and flexibility to a wide range of circuits.

Very Hard: it is the hardest tyre in the 2021 Pirelli range It is intended for circuits that put the most noteworthy energy loadings through the tires, which will commonly highlight quick corners, grating surfaces, or high surrounding temperatures. The compound sets aside more effort to heat up however offers the greatest sturdiness and gives low corruption.

Importance of Tyre Selection

The above-mentioned characteristics and details of every type of tyre show that every condition requires a different combination of tyres.

There is an inverse relationship between the grip and durability of the tyres. Using softer tyres will wear out quickly but it will provide a better lap time. When a team wants its driver to deliver the fastest lap time and get that bonus of 1 point, they need to use the super soft so that it has a competitive advantage over other racers. However, they can't only use super soft because then the team will be required to have more than 1 pit stop due to the lower lifespan of the tyre which will cost the team grid position. Losing the grid position means losing the rank in the race. This is because when the driver goes to the pit stop to change the tyres, the time it takes is included in the race time. In a track with higher surface temperature, a combination of hard and medium tyres is preferred that is because high temperature wears out the tyre quickly and on average the overall durability of each type of tyre reduces proportionately. On the contrary, a colder surface temperature track can be taken advantage of by the driver and a combination of soft and medium tyres should be used to improve the average speed since the durability of the tyres is high in such track conditions. In street races, cars require more grip due to the existence of sharp turns which leads to teams using a combination of soft and super soft. This gives the driver significantly better handling of the car and it also increases the speed.

To optimally finish a race, each team uses decisional theory where it can forecast the quantitative data such as the total life of the tyres and average speed loss per lap. Using this data, teams decide when to make a pit stop and which types of tyres to use next. For instance, after the use of soft tyres teams need to decide if they want to take an early pit stop and use hard tyres or delay the pit stop and later use medium tyres.

4. CONCLUSION

In formula one, the main objective of a team is to come to the top during the race. This is dependent on various factors and can be achieved by optimizing each constraint of the race. From selecting the type of tyre to making spontaneous decisions on every chicane, it's a matter of milliseconds that makes the difference.

To achieve the Leader position in the Grand Prix, a driver has to optimize each lap. This can be done by the OR techniques explained in our research paper.

As every track demands different strategies, the team has to formulate them thinking two races ahead every time.

Our objective was to minimize the lap time for a driver and to optimize that, we've used different OR techniques. It simulates the likelihood of various outcomes in a process that is difficult to anticipate, owing to random factors' influences. These methods help in figuring out how risk and uncertainty affect prediction and forecasting models.

We used these techniques since we had multiple constraints during every Grand Prix weekend and to improve on every weekend, we have to take into account a lot of factors including weather, track conditions, opponent's strategy, and budgetary constraints. When we account for all these limiting factors and formulate a strategy, we need a complex program to calculate and assess all the scenarios to give the best possible combination.

This simulation aids the understanding of how, with multiple constraints, a team can reduce the amount of time a car takes to finish one lap of the track. We can use these understandings in multiple areas of life as well. At every step of our journey, we need to optimize our decisions and every decision has multiple constraints.

This has helped us understand that even with a lot of constraints in place, you can compute and find the most efficient solution if the problem is worked out systematically.

The number of permutations during a Formula One race is so large that even the world's fastest supercomputer cannot process them all for each race. This is where Monte Carlo simulation comes into play. A team in F1 never has a fixed strategy it creates various scenarios according to the track. Some of the factors it takes into account are the possibility of overtaking on the first lap, the chance of crashes, the number of pit stops, etc.

Monte Carlo Simulation has made it a bit easier to assess the various risks each strategy offers and make the most out of the given track conditions, weather, and various other conditions.

In addition, the OR techniques we used to help us achieve our objective, are universal and can be applied to various aspects, irrespective of the area of application.

We are extremely grateful for the chance given to us.

5. LIMITATIONS

1. Although decision theory helps us choose the best option, if factors like weather change, crash, safety, change in opponents' strategy, etc. take place, one has to change their decisions mid-race to get themselves in a better position.
2. A challenge we faced during our research was not being able to cover every field of study related to our topic. F1 racing is a deep pool of knowledge and we were only able to dip our toes into a fraction of what it had to offer. This also means that the study still has a lot of scopes.
3. Time and cost: In F1 a fast-paced sport, decisions are often split second. FIA brings in various regulations and 2022 is no less. The FIA has introduced a budgetcap which will keep a level playing field for all teams going forward as FIA looks to become a little environment friendly given the huge amount of petrol it uses.
4. Lack of certainty: Decision theory helps choose the best option but if factors like weather change, crash, safety car, change in opponents' strategy, etc. take place you have to change your decisions mid-race to get yourself in a better position and decision theory is not fast enough to evaluate the best path forward.
5. All teams will be on the same level: The theories used are incredibly mathematical so, unless a team has data another team won't have it will not give the team an edge.
6. This model would have to be improved to be flexible for different distances between two drivers.
7. A safety car appearing in the first half of the race is not taken into account. This is because of the variability of strategies at this phase.
8. The tyres will not always last the exactly predicted periods. Different viewpoints like the optimal design of the various vehicles, the driver qualities, and the condition of the actual course can change these numbers.

6. RECOMMENDATIONS

1. Planning- We suggest that these techniques should be used in planning as, during the race, time is more important and shouldn't be wasted on thinking of making a decision.
2. Application of Game Theory- Since all teams have similar data and know what decisions are best, using game theory we can find out what decisions is the best knowing probably what decisions the other team would make.

Depending on the nature of the incident, the safety car may last a variable number of minutes per lap. The model should be adjustable for this.

REFERENCES

[1] Iyengar, R. (2017, September 26). *Roshni Iyengar*. Retrieved from Medium: https://medium.com/speedbox-is-typing/the-logistics-behind-f1-7537e445de20

[2] Iyengar, R. (2018, February 15). *WTF1*. Retrieved from Youtube: https://www.youtube.com/watch?v=BQ1xHbr9JIQ

[3] Martin, N. (2014, May 6). *Neil Martin*. Retrieved from University of Southampton: https://www.southampton.ac.uk/maths/news/2014/05/06_how_mathematics_can_make_the_difference.page

[4] Mello, J. C. (2005, May 15). *João Carlos Correia Baptista Soares de Mello*. Retrieved from Scielo: https://www.scielo.br/j/cebape/a/DVbhyHgfZ3LSWJfHBxkrTHm/?format=pdf&lang=en

[5] R.Catchpole, K. (2007). *Ken R.Catchpole*. Retrieved from Wiley Online Library: https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1460-9592.2006.02239.x
[6] Singh, S. (2021, April 30). *Sarbjeet Singh*. Retrieved from Emerald: https://www.emerald.com/insight/content/doi/10.1108/JQME-07-2020-0062/full/pdf?title=gone-in-2s-a-deep-dive-into-perfection-analysing-the-collaborative-maintenance-pitstop-of-formula-1
[7] SportsJone. (2021, September 11). *Formula One: Dutch Grand Prix: Netherlands: Vote: Driver*. Retrieved from https://sportsjone.com/formula-one-dutch-grand-prix-netherlands-vote-driver/
[8] Spurgeon, B. (2008, July 4). *Brad Spurgeon*. Retrieved from New York Times: https://www.nytimes.com/2008/07/04/sports/04iht-SRSTRATEGY.1.14234141.html
[9] Stavropoulos, V. (2018, May 18). *Vasileios Stavropoulos*. Retrieved from Statathlon: https://statathlon.com/analysis-of-the-pit-stop-strategy-in-f1/
[10] Wieczorek, A. (2019, December). *Adam Wieczorek*. Retrieved from Research Gate: https://www.researchgate.net/publication/339643688_Logistics_in_Racing_Sports_on_the_Example_of_F1

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