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The Applications of Operations Research in Formula One

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***Abstract*: The following research paper is an overview of our findings of the applications of operations research in Formula one. It is an overview of how operations research is used in every aspect of the working of Formula from the cars itself to strategies of the race. It also looks into the revenue of the sport, simulations and the workings of operational research in pit stops. This was done by conducting a detailed study of various research articles. All of these advanced methodologies are used to shave of a few valuable seconds through the race.**

***Keywords*: Formula One, Operations research in Formula One, Simulations and revenue.**

1. Introduction

A rapid stop can sometimes be the difference between the race leader retaining his minor grand prix advantage to squandering a place on the podium; and losing out on a victory and vital points. “Good pit stops are hard to come by, when they do they win you races”- Niki Lauda, three-time F1 champion.

Formula one is a huge global sport estimated to be worth $4 billion annually. (economywatch, 2015) it is the most prestigious and fastest car racing championship in the world. It is the most watched annual sporting event in the world. In 2018, it had a 10% increase in the number of viewers globally reaching 490.2m. (Formula one, 2019). F1 employs around 5000 people in more than 30 countries and is a major source of employment. It was originally predominant among the aristocrats who had a passion for racing. It did not have any sponsors and the only source of revenue was the sale of the tickets. However, it gradually started to gain popularity in the 1970s and soon had sponsor logos on each of its cars. Currently, all 12 teams of formula one are worth $4.05 billion and the average F1 team is worth $337 million generating an average annual revenue of $145 million with Ferrari, McLaren and Redbull being the top three teams (Forbes,2019). It was inaugurated in 1950 and FIA Formula One World Championship has been a premier form of racing ever since. The F1 race cars are the world’s fast regulated racing cars with each car constructed by the racing team itself. Even though Europe is the sport’s traditional base, 11 out of 21 races are organised out of Europe in 2019.

Management science is a problem solving process used to develop various models to represent both simple and complex functional relationships and help in the decision making in order to solve various problems. Management science is applied in almost every possible field such as aviation, manufacturing, services, military, sports etc.

One problem commonly seen during these races are issues related to the pit stops. A pit stop is where the cars stop during a race in order to refuel, change the tyres, do the repair work or mechanical adjustments, or any of these combination. The perfect pit stop is something you frequently hear, not something you see.

The advancement of technology in the field of simulation used in formula one and the applications of basic operation research concepts for strategy development have become vital parts of the sport.

The millions of terabytes of data accumulated in this sport per team means nothing if not analysed properly this is where simulation which is a crucial part of operations research comes into play to save important seconds, Another crucial part of operations research used is the strategy and planning of pit stops.

The major hurdles operations research in the car-racing industry help us optimize give the driver an unprecedented advantage in this game of margins are to optimize the location of the pit crew, refueling and finding out the best possible “path” to drive on throughout the race.

2. Overview

In the last 10 years the F1 one industry has been characterised by intense competition and cut-throat battles, as well as a high degree of technological adoption. New audiences have flourished around the world as the broadcasting has reached every corner of the globe.

A $2.6-billion-dollar budget in the overall industry fuels these teams. With money flowing from every channel it certainly has a lot of money riding on it. The sport has grown year on year continuously even through a global economic meltdown which is a testimony to the strong viewership it has around the world. The total viewership of the sport stands at 1.310 Billion viewers for the last season.

Every year the industry has been finding different revenue streams the most recent revenue streams added is the use of social media- and an on app live streaming feature. In the last year the social media revenue accounted for 5% of the total revenue generated.

The current industry scenario looks unstoppable with more

and more money and viewership constantly flowing in and it seems to be ever growing and the future of this industry looks extremely bright. F1 has many significant positive impacts and importance in various sectors such as with the annual cost of running a mid-tier team—designing, building, and maintaining cars, pay, transport—being US$120 million, Formula One has a significant economic and job-creation effect. F1 has created one of the most widely selling merchandising markets.

A. *Current happenings*

Active suspension: The recent advancements made in the suspension technology of the cars have made a monumental difference in the turning speeds of the cars. It uses a synthetic spring linked to the cars electronic motors, active suspension could better control the car's immense downforces and compensate for conditions. The ride height for the entire race was kept constant and maximized grip and aerodynamic efficiency.

DRS rule: Drag reduction system, a rule in F1 introduced in 2011, is a rule which was introduced to promote overtaking by reducing drag on the car following the car. Drivers are allowed to use the DRS freely during practice sessions and qualifying in the designated zones and when they are running within one second of the car ahead in the race.

Aerodynamic rule changes: Formula One has approved new aerodynamic rules for the year 2019 which aims at promoting closer racing and tighter finishes.

Various new measures have been taken such as structural changes in the design of the cars such as a larger wing span and front brake ducts without winglets and wider and deeper rare wings.

3. Research objectives

1. *To understand:* The workings of modern technology and algorithm based solutions such as simulations used in the formula one industry. Also to understand certain crucial aspects of the sport such as pit stop in detail.
2. *To find:* The current simulation models and active strategies used by teams to help shave of a few seconds. Also to find at what level can operations research can be used in the sport.
3. *To elaborate:* To elaborate the usage of simulation in general in different sports and also how exactly it can be used in the formula one industry. Also to see the extent to which operations research in used in race strategy such as pit stops. To elaborate how simulation program taking into account multiple factors helps the team understand how the quickest lap time can be achieved.
4. *To outline:* To outline how technology adoption helps improve every avenue of the sport right from the cars to the evolution of different revenue streams such as social media.
5. *To describe:* The effectiveness of simulations and race strategy using operational research tools for race strategies and simulations. The use of operational research tools such as simulations and how operational research helps in race strategies such as pit stops.

4. Research methodology

This paper selects, analyses and consolidates information from various research papers, which have findings related to the applications of operation research and operational research tools in Formula One. A vast number of research papers and internet websites were read to consolidate information and after understanding the workings were compiled to come to a conclusion. Only secondary data was analysed throughout the working of this research paper. Different simulation models were studied and the working of different simulation models used in various aspects of the sports were summarised. Various models like Monte-Carlo simulation, tire model, fuel model and lap time models and pit stop models were studied.

5. Literature review

A. *Revenue in formula one*

Ever since its inception in 1950, Formula one has been one of the strongest revenue generating sports through economic downswings and upswings. It has always been successful in in maintaining record revenues. With sponsors, race organizers and millions of enthusiasts queuing up for a piece of the action, star names and icons, the sport has always been stuck in the financial fast lane.

Since the rearrangement of the management of Formula One's commercial rights in 1970, the sport has transformed into a multi-billion-dollar business it is now. The sports revenue through multiple channels. The formula one federation makes money mainly through four major channels, race fees, sponsorships, television rights and corporate merchandising and hospitality deals. The federations revenues have shot up from $729 million to $1.523 billion in 2011 and about $4 Billion in 2018. Last year out of the $4 billion dollars generated $1 Billion accounted for television rights, $273 million from advertisers such as Rolex and Emirates airline. Corporate hospitality tickets sales which along with miscellaneous sources came to $305.1 million. Followed by $608.3 Million event organisers paid to host these F1 races. $259 Million from selling track side advertising. The hosting fees typically accelerate by 5% annually due to escalators in the race promotion contracts. It has led to the biggest payers having an annual bill north of $70 Million which makes a massive dent in their bottom line. F1 has a worldwide viewership of 580 million over the world giving them a strong base from revenue growth.

F1 teams make their money mainly through one source, the most important channel which are sponsorships. On an average team sponsorships are around two or three year contracts. Huge companies sponsor F1 teams such as UPS, Ray-Ban, Phillip Morris. Marlboro has entered into a record breaking sponsorship contract worth $150 Million with Ferrari to rename their team 'Scuderia Ferrari Marlboro'.

The second most important revenue stream is the most important for the smaller F1 teams which don't bring in as much money as the bigger teams: Formula One Group (FOG Money). At the end of each year, the FOG ends up with a billionaire's sum from the year's business dealings. This sum of money is then distributed amongst the teams according to the last agreement signed in the previous year. In 2017, each team was awarded $36 Million each from the lockbox just to continue in the formula one world. However, teams do not receive this money unless it's their third consecutive racing. Teams also receive bonuses for winning the annual constructors championships and for other competitive measures.

B. Simulation in sports

Sport professionals are always looking out for different ways to improve their performance and at the same time ensure comfort and reduce risk of injury. Similarly, sport equipment manufacturers must also develop better products so as to increase their reliability in challenging conditions. Engineering simulation is a tool being widely used in the recent times. It is used to predict the behaviour of an athlete under various conditions. Through a coded programme this helps professionals understand the influence of certain factors on an athlete's overall performance. By simulating these factors, the consequences of these factors can be predicted and hence used to the athlete's advantage so as to adjust his or her actions in accordance with these factors. Sporting goods manufactures can use these predictive simulation models to make better quality goods by simulating their products under extreme conditions and evaluating the durability and strength. The highest quality of products can be made when an engineering simulation is run on the complete system which is this case is the product, the athlete and the conditions under which these usually are to be used. (Blocken, B, Toparlar, Y. (pp. 178–186). Engineering simulation finds a wide range of application in the sports industry it is used practically in almost these days. It is actively used in golf. The simulation model used here takes into account the impact between the club and the golf ball and the flight of the ball. Aerodynamics play a key roll once the ball in in the air in this model. This studies the structural rigidity of the club designed to maximise the transfer of energy from the club to the ball.

C. Winter Sports

Simulation models are used in sports such as Skiing, snowboarding and ice hockey, even sports like bobsleigh take advantage of engineering simulation. In all of the speed related sports the most important thing studied is the contact with the snow and the aerodynamics. Simulations are run taking into account various factors such as the shape of the shoes or boots, the texture of the suit. The design of the ski or bob sled. Any competitive advantage is looked for by running thousands of simulations to find the right outcome. The robustness of the materials composing equipment can be guaranteed or improved through quick and cost-effective computer-based testing.

D. Simulation in F1

Simulation techniques are an integral part of formula one. It finds applications in various parts of Formula One. The most iconic application of simulation techniques in recent times has been the development of the "Simulator". A simulator is a massive computer larger than a studio apartment. It has a full range of hydraulics that provide or mimic every motion throughout the race- this allowed the race teams and drivers to learn circuits before the races, to asses try out new parts or modifications made of their cars.

The invention of the simulator has solved another major problem the cost of testing and the availability of the testing tracks. Drivers from top teams used the circuits for hours at end just before the grand prix because of the very fact that big teams could afford hiring the track for practice. This put the smaller teams at a huge disadvantage.

Also, all teams need to try out new technology and ideas. New engine parts or wing designs must be tested repeatedly to shave of precious seconds. With the imposition of practice times per team, all racing teams have turned to virtual simulations to save time and costs.

Race simulators have also been beneficial when the weather conditions do not permit drivers to test out their cars and hence it still gives the drivers an opportunity to practice and learn tracks.

The most important use of simulation techniques in Formula One has been the formulation of race strategies by running hundreds of active simulation models simultaneously before and during the races.

"Race experts say that races are won in the factory instead of on the circuit. Formula one teams collect huge amounts of data in order to predict and improve performance. The Red Bull Racing team has sixty engineers present in the pit box and thirty engineers in England during a racing weekend. The data from the on-going race reaches the engineers back at the factory in England within 300 milliseconds to run simulations during the race or to adjust the race strategy whenever a tire changing or an overtaking opportunity occurs. Race strategy decisions can be crucial in winning a formula one race and can help formula one teams plan and evaluate their strategies. Due to these simulation techniques being used several policies have been changed or new policies been implied such as the ban of refueling during the race and the implementation of drag reduction system in certain sectors of the circuit.

Another simulation model was developed in 2016, which takes into account most important changes in regulations such as the safety car and drag reduction system. These models must have the capability to continuously be changed according to new policies and regulations and lap times. These models are also capable of taking into account random happenings during the race and come up with a new race strategy on the spot. The newly made model in 2016 also describes the influence of fuel consumption and tire degradation on the lap time based on lap time data from races of 2016.

In addition, the simulation model also takes into account certain things like the mixing of cars at the beginning of the race, pit stops, overtaking actions, safety car situations and driver retirements.

6. Pit stops

Formula One is such a big business, with so much resting on victory, that the decision of when to stop can no longer be based on calculations. The decision is based on cold, hard numbers. Operational researchers build mathematical models which decipher data on relative track positions, fuel consumption, tyre wear and weather conditions, along with a host of other factors. These computer models can run millions of scenarios simultaneously and find the strategies most likely to succeed. They can even say how likely they are to work. This allows team bosses to understand the relative risks associated with each strategy and decide which course to take.

It is vital finding the optimum time to come in and change your tyres and amount of time spent at the pit stops. The computer models could reveal that waiting another lap, whilst slowing you down a bit due to further tyre wear, could bring you out of the pit lane free to motor on your shiny new tyres, more than making up for the delay of the extra lap.

Operations research in this aspect is extremely valuable. The method of calculating the time spent on the pit stop can be invaluable. Or helps us to know how much time spent at the pit stop will actually give an advantage over other cars. The companies with the help of or decide on which lap should the car come at the pit stop and also how the engineers will work on which car parts in those precious seconds.

Fuel consumption is another aspect where operations research is used. It is not as simple as it looks where let's say after a certain number of laps, the car visits the pit stops. Calculating when and how much fuel should be filled in order to make sure that it does not fall behind its competitors is where operations research comes into play.

Weather reports, tyre changing all these aspects are influenced by the operations research. Formula one is a calendar event with races occurring at different destinations in different weather conditions. Operations research here is needed, let's say there are extremely high temperatures on race day, then the tyre pressure should be lesser on that day.

7. Findings

A. Time saving

Simulations run before and during the races help take into account multiple factors which help save crucial seconds in a race. These simulations are run simultaneously during every race to find an overtaking opportunity.

The crucial importance of pit stops in formula one races, how pit stops have reduced from minute- long pit stops to just 2-3 seconds due to the constant advancement of technology and operations research in the field of F1. The optimum utilization of man power, technology and race strategies have helped reduce pit stops from a minute to seconds.

B. Asset/Labour Allocation

The micro-allocation of jobs to each of the crew members and this has significantly improved pit stop times. Since these jobs are allocated and practiced over and over again has dramatically reduced time. Which again goes to show the efficient allocation of tasks reduces time.

C. Pit Stop Timing

Using operations research to find out the best time to take a pit stop based on factors such as weather conditions, competitor's mistakes and over-crowding in the pit lane. Weather factors are taken in account and accordingly the number of laps the car can travel on those sets of wheels are predicted these number of laps are the co related with the number of competitors going to take a pit stop after the same number of laps, these models help optimize the track and pit stop timings of the driver.

D. Weather based simulation

Simulator allow the drivers to take virtual laps around the track so as to know every corner of the track before racing. Simulators also allow the driver to operate under different conditions which indirectly leads to a change in the tyres a driver uses on an actual race day. For example, on an extremely hot day the tyre pressure must be kept minimum to avoid bursting.

8. Limitations

The main challenge faced was due to the lack of reliable data which limited the scope of analysis and size of our research paper. Another factor was lack of prior research on simulation specifically in relation to formula one. The data available on this topic was insufficient due to lack of research papers. Also, being a student, we have limited knowledge on the application of our topic in F1 industry. The time was another constraint. Since it is a broad topic and the industry is dynamic i.e changing constantly at a fast pace it was difficult to incorporate different technical aspects of the algorithms used. The lack of technical knowhow as certain aspects of the study required intense knowledge of physics along with operations research was challenging.

9. Conclusion

From all the discussions that have been held, it has to be concluded that the minimization of time spent on pitstops and how the derivation of race tracks and simulation race tracker prove to be a vital part of the entire process. Aero lap is a lap simulation tool used for analyzing and maximizing performance of race cars over a given race track. Unique algorithms along with this will help to derive best and most efficient way of finishing the race efficiently. All crews use the similar methods along with different algorithms to get an up on

the competitors.

The basis of the entire Formula One is based on pitstops and the time spent there. Here there a variety of parts of the car and each crew will be using different company parts in order to make sure that the car going back into the race again after the pitstop is at its best and at its best. It is reviewed that the key role of pit stops as a main part of a well-designed F1 race strategy. The main objective is to analyze the importance of an efficient pit stop and the impact that it has in the race.

These form an integral part of the entire formula one process and are key elements in optimising the best way to finish the race.

References

[1] J. Bekker, 2008, Planning Formula One Race strategies using discrete event Simulation.
[2] O. Donoghue, 2005, The role of simulation in sports tournament design for game sport
[3] Yigal Gerchak, 1994, Operations Research in Sports.
[4] W. D. Kelton, 2014, Simulation modelling Sand Analysis.
[5] Blocken B, Toparlar Y, Aerodynamic Drag in Formula One.
[6] Giacomo Perantoni, 2014, Optimal Control for formula one with variable parameters.
[7] Thomas Muehlbauer, 2010, Relationship Between Starting and Finishing Position in Formula One Car Races.
[8] Budzinski, Oliver, 2012, Measuring Competitive Balance in Formula One Racing.
[9] D. J. N Limebeer, 2014, Optimal Control of Formula One Car energy recovery systems.
[10] Hans Pacejka, 2007, The magic formula tyre model.
[11] Claudia Sulsters, 2018, Simualting Formula One Strategies.