McMaster University

PROJECT RAPTORS REBOUND

DAT 205 - CAPSTONE

**WINTER 2021 – GROUP 1**

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# Executive Summary

## How to improve Toronto Raptors’ chances at another championship run while preserving the team’s long-term future.

### Problem Description

Toronto Raptors: the only Canadian franchise in NBA. The raptors won their first NBA Championship in 2019. However, the team’s performance has been in decline since then. The team’s General Manager is seeking recommendations on improving the team’s chances at another championship run while preserving the team’s long-term future. The GM is also very keen on evaluating if with the recommendations, Toronto Raptors improve performance-to-cost effectiveness while retaining the public interest in the team.

### Analysis

Something about how we reached the recommendations.

### Recommendations

Recommendations

### Additional Considerations

Considerations

# Business Goal

The Toronto Raptors are an NBA championship team with a $2.5 billion market capitalization. The franchise added key players in 2019 who contributed to critical wins during the season and championship playoff run. The team won their first ever championship title in that season. The team’s performance has been in decline since being crowned 2019 NBA champions.

The team’s General Manager (GM) and owners are seeking recommendations on improving the team’s chances at another championship run while preserving the team’s long-term future. The recommendations will be in the form of marginal/minor improvements to the player roster. The stakeholders intend to either maintain or improve on the number of wins during the regular season and more importantly, during the playoffs.

The organization wants to retain a public interest in the team while improving the team’s performance without rebuilding the entire team. A spot in the NBA finals while maintaining the number of regular-season wins would be ideal.

# Objectives

To attain the requirements outlined by the management, we have set 2 objectives. we are looking to determine what features affect team wins/losses and predict how it can be improved/reduced through changes in the team’s roster.

1. The primary objective of this analysis is to determine which features are important to the Toronto Raptors team to produce more wins in the regular season and the playoffs.
2. The secondary objective is to review team players’ performance-to-cost effectiveness.

The scope of this analysis will be to focus on the historical player data from 2005 to 2020 as this closely represent the players of the current era. The performance baseline of the team and players will be established using the data for The Toronto Raptors 2019-2020 season. These statistics will be used to indicate performance features for the team and the individual players.

To simplify the analysis the following assumptions were made:

* Changes are only applied to the Toronto Raptors; the statistics from other teams are not affected or changed.
* Obtaining any players is up to the Raptors’ GM to determine if they will pursue the player via free agency, trading of players, etc.

# Data Description

### Gathering data – nba api

For the primary objective, we have consumed the data hosted by [nba.com](http://www.nba.com); It is made available via webservices through [stats.nba.com](http://stats.nba.com). A player or team’s base statistics are updated simultaneously with the game and in real time. nba\_api is an open access API client library for Python developed by Swar Patel. There are more than 250 endpoints (the method to request information through the API) available.

#### Understanding the Data - PlayerGameLogs

PlayerGameLogs endpoint gathered the statistical data of each player in each game by season (figure 1). Input to this endpoint is the season year (For example:’ 2014-15’). The response from the API will be 34 parameters. Each row represents an entry for a player log for a game. This consists of features from the year 1946 to the present day for roughly 1.3 million records.



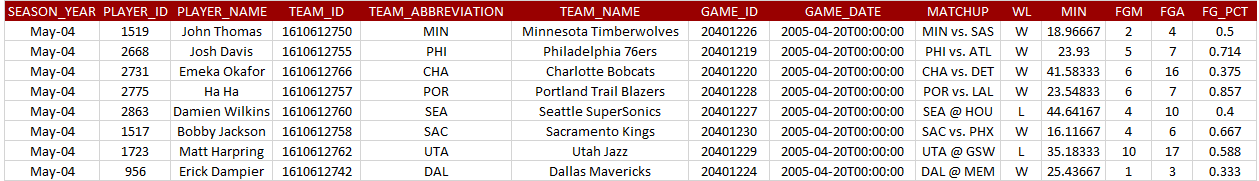


Figure 1 Example PlayerGameLogs data subset

Feature WL in the above figure indicates win or loss of the game. As an exercise of this analysis, the win or loss is to be predicted based on players’ performances, which makes WL the target feature. Classification models such as Logistic Regression, Decision Tree, or Random Forest will be applied for the analysis.

List of Output variables from the API endpoint

|  |  |  |  |
| --- | --- | --- | --- |
| **Attributes** | **Data Type** | **Example value** | **Definitions** |
| **SEASON\_YEAR** | STRING | 2015-16 | NBA season |
| **PLAYER\_ID** | INT | 202710 | Player Unique ID |
| **PLAYER\_NAME** | STRING | Jimmy Butler | Player name |
| **TEAM\_ID** | BIG INT | 1610612741 | Team Unique ID |
| **TEAM\_ABBREVIATION** | STRING | CHI | Team 3-character abbreviation |
| **TEAM\_NAME** | STRING | Chicago Bulls | Team name |
| **GAME\_ID** | STRING | 0011500103 | Unique ID for the game |
| **GAME\_DATE** | DATETIME | 2015-10-23T00:00:00 | Date/Time game is played |
| **MATCHUP** | STRING | CHI vs. DAL | Teams featured in the game |
| **WL** | STRING | W | The player who was on the team who won/lost |
| **MIN** | FLOAT | 24.25 | Minutes Played The number of minutes played by a player |
| **FGM** | INT | 2 | Field Goals Made The number of field goals that a player has made. This includes both 2 pointers and 3 pointers |
| **FGA** | INT | 7 | Field Goals Attempted The number of field goals that a player has attempted. This includes both 2 pointers and 3 pointers |
| **FG\_PCT** | FLOAT | 0.286 | Field Goal Percentage The percentage of field goal attempts that a player makes Formula (FGM)/(FGA) |
| **FG3M** | INT | 0 | 3 Point Field Goals Made The number of 3-point field goals that a player has made |
| **FG3A** | INT | 0 | 3 Point Field Goals Attempted The number of 3-point field goals that a player has attempted |
| **FG3\_PCT** | FLOAT | 0 | 3 Point Field Goal Percentage The percentage of 3-point field goal attempts that a player makes Formula (3PM)/(3PA) |
| **FTM** | INT | 0 | Free Throws Made The number of free throws that a player has made |
| **FTA** | INT | 0 | Free Throws Attempted The number of free throws that a player has attempted |
| **FT\_PCT** | FLOAT | 0 | Free Throw Percentage The percentage of free throw attempts that a player has made Formula (FTM)/(FTA) |
| **OREB** | INT | 0 | Offensive Rebounds The number of rebounds a player has collected while they were on offense |
| **DREB** | INT | 3 | Defensive Rebounds The number of rebounds a player has collected while they were on defense |
| **REB** | INT | 3 | Rebounds A rebound occurs when a player recovers the ball after a missed shot. This statistic is the number of total rebounds a player has collected on either offense or defense |
| **AST** | INT | 6 | Assists The number of assists -- passes that lead directly to a made basket -- by a player |
| **TOV** | INT | 1 | Turnovers A turnover occurs when the player on offense loses the ball to the defense |
| **STL** | INT | 1 | Steals Number of times a defensive player takes the ball from a player on offense, causing a turnover |
| **BLK** | INT | 1 | Blocks A block occurs when an offensive player attempts a shot, and the defense player tips the ball, blocking their chance to score |
| **BLKA** | INT | 0 | Blocks Against The number of shots attempted by a player that are blocked by a defender |
| **PF** | INT | 3 | Personal Fouls The number of personal fouls a player committed |
| **PFD** | INT | 0 | Personal Fouls Drawn The number of personal fouls that are drawn by a player |
| **PTS** | INT | 4 | Points  The number of points scored |
| **PLUS\_MINUS** | INT | 11 | Plus-Minus The point differential when a player is on the floor |
| **DD2** | INT | 0 | Double Doubles The number of double-doubles (double-digit number total in two of the five categories in a game) a player achieves |
| **TD3** | INT | 0 | Triple Doubles The number of triple-doubles (double-digit number total in three of the five categories in a game) a player achieves |

Figure 2 Available features for data between 2005 to 2020 (NBA Media Ventures, LLC., 2021)

#### Understanding the Data – NBA player salary data

For the secondary objective, we have used multiple data sources. This data is not provided by NBA. We have retrieved historical player salary data from [espn.com/nba/salaries](http://www.espn.com/nba/salaries). We have merged the future salary data from [hoopshype.com/salaries/](https://hoopshype.com/salaries/) to the salary dataset. This was done by web-scraping using python libraries.

The Salary data consists of 16 possible features from the year 2015 to the 2025(If contracted) for approximately 500 players.

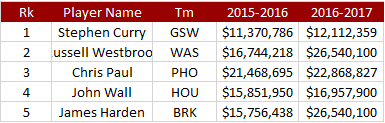


Figure 3 Example NBA Salary data subset

| **Feature** | **Data Type** | **Example value** | **Definitions** |
| --- | --- | --- | --- |
| **Rk** | INT | 1 | Current NBA rank of the player |
| **PLAYER NAME** | STRING | Stephen Curry | Player name |
| **Tm** | STRING | GSW | Team’s 3-character abbreviation |
| **YYYY-YYYY** | FLOAT | 11,370,786 | Salary (in US dollars) for the given NBA season year  Column YYYY-YYYY represents the NBA season year |

Figure 4 Available features for salary data between 2015 to 2025 (ESPN and HoopHype)

# Project Planning

The overall implementation will be in 5 phases with a deliverable provided at the end of each phase. Completion of the final report is targeted for Apr 15th along with a presentation to summarizing the recommendations outlined in the report.

High Level Milestones: Summary of important deliverable dates

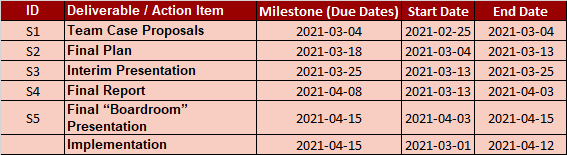


Figure 5 High level project schedule and milestones

Detailed Project Plan: Detailed project schedule



Figure 6 Gantt Chart of the overall project plan

# Implementations

The model from this analysis will be used by Business or Data analysts working for Toronto Raptors basketball team to improve the performance looking at any set of years. The analyst can choose which performance factors they would like to focus on.

The tools used:

* Visual studio code as an Integrated Development Environment
* Python as the programming language
* Jupyter notebook
* Microsoft Access, Microsoft Excel, and csv as file formats for scraping data.
* Git as a collaboration repository: <https://github.com/bhavikapatil/Capstone> (currently, a private repository)
* Google drive for large files (Private Github doesn’t support files larger than 100 MB)
* GitHub desktop for a Git client
* Microsoft Office as reporting tools
* Tableau desktop for data visualization
* Microsoft Visio

# Data Preparation and Analysis

For the Primary objective, we are identifying the most important features for Toronto Raptors to win.

For the secondary objective, we have strategized to identify the underperformers (based on the features identified in the Primary Objective), and replace them with some non-Toronto players who rate better for those features.

### Phase 1: Feature Selection

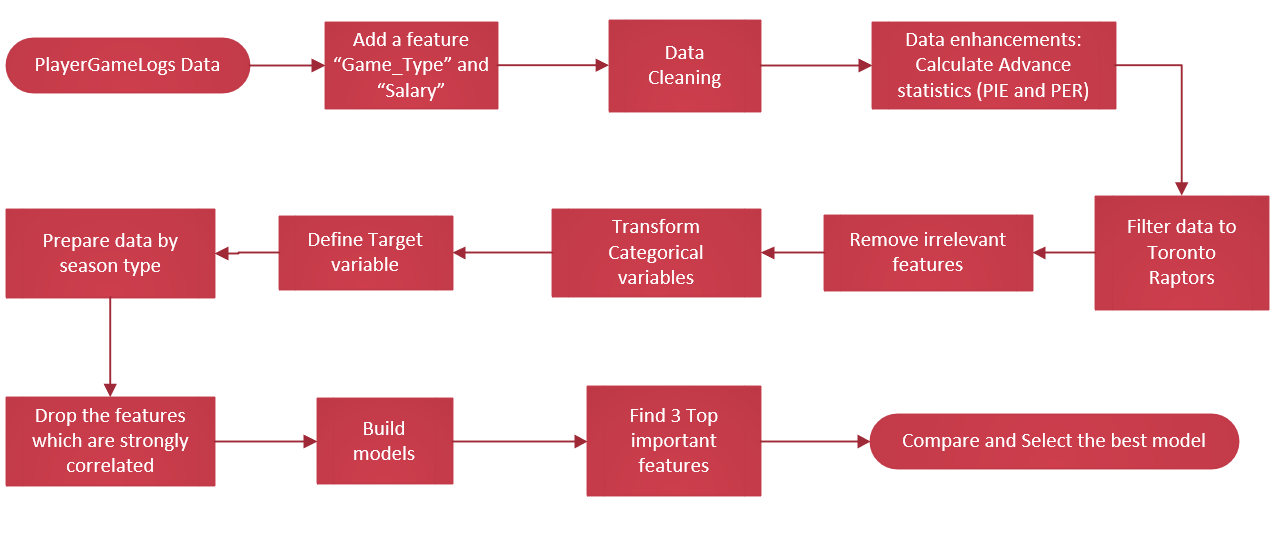


Figure 7 Process for Phase 1: Feature Selection

Reviewing/Cleansing the data

The initial data set is gathered through the nba\_api using the endpoint PlayerGameLogs. A new feature called Game\_Type is applied to each record to categorized by Pre-Season, Regular Season, or Playoffs games from 2004 to 2020. Salaries are related to each player. The focus of the data was on the Regular Season for our analysis. Pre Season games held little value as veteran or marquee players would not play to their typical abilities unlike new players who need to prove their worth to the coaching staff. Playoff games were excluded as the opposite extreme of Pre-Season games.

An Initial analysis of this data indicated minimum data cleansing was required under the feature PLAYER\_NAME. Null values were found for 740 records. No data cleansing was required as this records were under the Pre Season.

Data Transformation (Enhancement)

Additional features were appended to enhanced the data. These were advanced NBA statistics analysts used to distinguish player utilization or effectiveness which we will use later in our modeling and analysis. We selected to advanced statistics:

* Player Efficiency Rating (PER)
  + This is a metric that take a player’s individual statistics to measure their efficiency in a game(s). More offensive minded players benefit more than defensive players.
  + The player efficiency rating (PER) is a rating of a player's per-minute productivity. PER boils down all a player's contributions into one number
  + The formula is defined as

PER = (FGM x 85.910 + STL x 53.897 + FG3M x 51.757 + FTM x 46.845 + BLK x 39.190 + OREB x 39.190 + AST x 34.677 + DREB x 14.707 - PF x 17.174 – (FTA-FTM) x 20.091 – (FGA-FGM) x 39.190 - TOV x 53.897) \* (1 / Minutes)

* + PER takes into account accomplishments, such as field goals, free throws, 3-pointers, assists, rebounds, blocks and steals, and negative results, such as missed shots, turnovers and personal fouls. The formula adds positive stats and subtracts negative ones through a statistical point value system. The rating for each player is then adjusted to a per-minute basis.
* Player Impact Estimate (PIE)
  + PIE measures a player's overall statistical contribution against the total statistics in games they play in. PIE yields results which are comparable to other advanced statistics (e.g. PER) using a simple formula.
  + The formula is defined as

PIE = [PTS + FGM + FTM - FGA - FTA + DREB + (0.5 \* OREB) + AST + STL + (0.5 \* BLK) - PF – TOV] / [GmPTS + GmFGM + GmFTM - GmFGA - GmFTA + GmDREB + (0.5 \* GmOREB) + GmAST + GmSTL + (0.5 \* GmBLK) - GmPF – GmTOV]

Note: Statistics prepend with “Gm” refers to the sum of the value for that feature for the entire game

Filter data by Toronto Raptors data

We are only focusing on what type of features will help Toronto Raptor win games based on the players of the past. This reduced the number to over 13000 records.

Feature Reduction (Part 1)

Features selected for removal were based on experience and initial analysis of the data on how these types of values would impact the models. These features were removed as these typically would not have an effect on the target feature Win/Loss (WL)

* Unwanted Numerical Features
  + PLAYER\_ID
  + TEAM\_ID
* Unwanted Categorical Features
  + PLAYER\_NAME
  + TEAM\_ABBREVIATION
  + TEAM\_NAME
  + GAME\_ID
  + GAME\_DATE
  + MATCHUP

Data Transformation (Encoding, data separation)

Label Encoding and value replacement were applied to transform categorical values (SEASON\_YEAR, Game\_Type) to numerical values. These features would eventually be excluded as being judged as irrelevant features.

The data was separate into the TARGET feature (Y) and the remaining features (X).

Feature Reduction (Part 2)

Correlation Matrices (heat maps were plotted to determine any possible correlation among the remaining features.

* Correlation Matrix



Figure 8 Heat map for Toronto Raptors (Regular Seasons 2004 to 2020)

From Figure [*Figure 9 Heat map for Toronto Raptors (Regular Seasons 2004 to 2020)*], any features that have correlational values above 0.85 are designated to be too closely related. We found several feature combinations (Figure [[*Figure 10 Feature correlations with values greater than 0.85*]] where the features (PTS, FGA, FTM, REB) added no benefit to the model analysis and were selected for feature removal.

|  |  |
| --- | --- |
| Feature combination | Correlation Matrix Value |
| FGM vs PTS | 0.96 |
| FGA vs PTS | 0.88 |
| FGM vs FGA | 0.97 |
| FTM vs FTA | 0.97 |
| REB vs DREB | 0.93 |

Figure 9 Feature correlations with values greater than 0.85

The Heat Map was replotted (Figure [*Figure 11 Heat map for Toronto Raptors (Regular Seasons 2004 to 2020) after removal of several features with values > 0.85*]) to ensure no other redundant features were in the dataset.

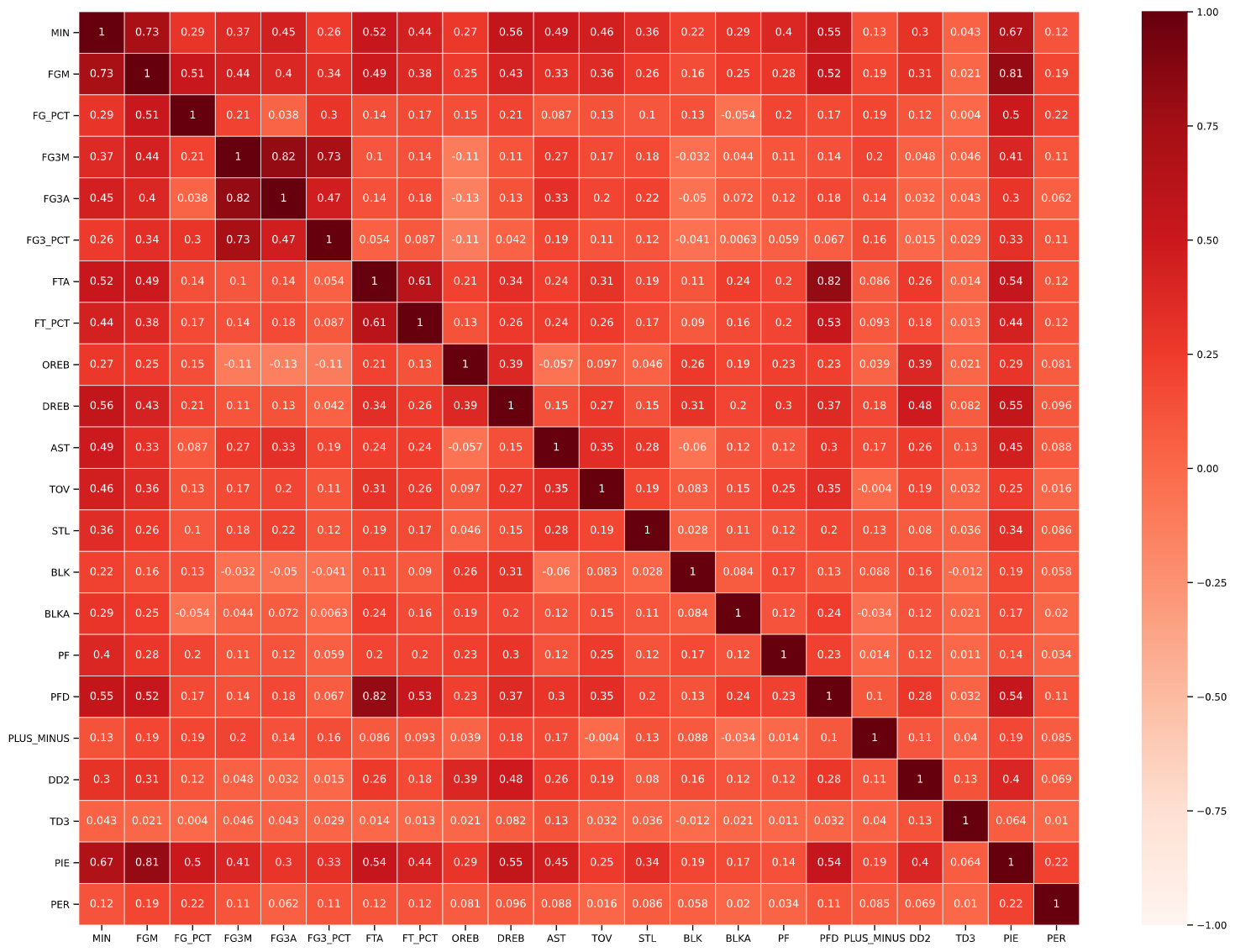


Figure 10 Heat map for Toronto Raptors (Regular Seasons 2004 to 2020) after removal of features with values > 0.85

Model Analysis

Once the data was split into 70% training and 30% test data we processed the data using 3 tuned algorithms: Logistic Regression, Decision Tree, and Random Forest. Random Forest showed the best results scoring the highest in all 4 analysis categories (Figure [*Figure 11 Accuracy / F1-Score / Sensitivity / Specificity by Model Comparison*]) and the highest results of all 3 models where the model placed the most importance on the features PLUS\_MINUS, PER, and PIE. (Refer to Figure [*Figure 12 Plot of Feature Importance by Model*]). These 3 features consisted of 60% of the importance.

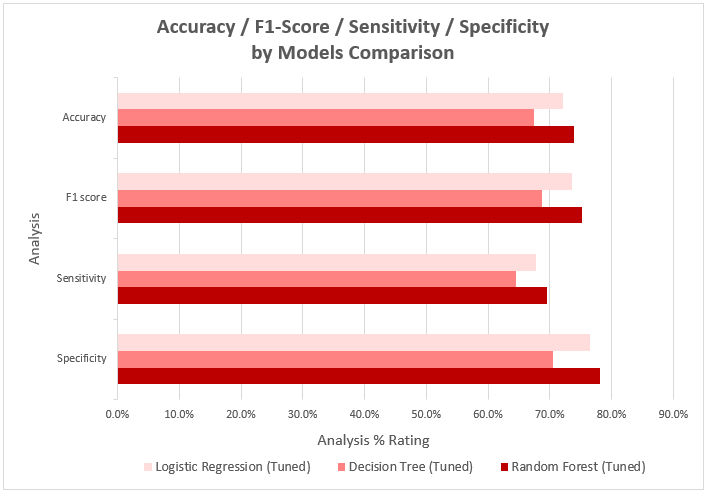


Figure 11 Accuracy / F1-Score / Sensitivity / Specificity by Model Comparison

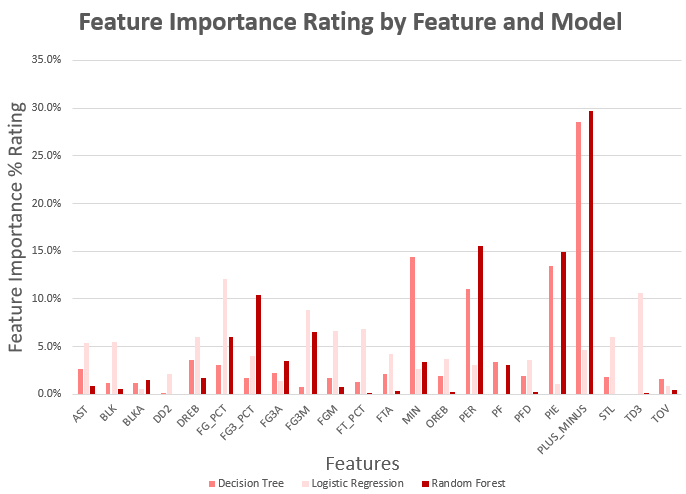


Figure 12 Plot of Feature Importance by Model

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Logistic Regression** | | **Decision Tree** | | **Random Forest** | |
| **Feature** | **Feature Importance** | **Feature** | **Feature Importance** | **Feature** | **Feature Importance** |
| FG\_PCT | 12.1% | PLUS\_MINUS | 28.6% | PLUS\_MINUS | 29.7% |
| TD3 | 10.6% | MIN | 14.4% | PER | 15.5% |
| FG3M | 8.9% | PIE | 13.4% | PIE | 15.0% |
| FT\_PCT | 6.8% | PER | 11.0% | FG3\_PCT | 10.4% |
| FGM | 6.6% | DREB | 3.6% | FG3M | 6.5% |
| DREB | 6.0% | PF | 3.4% | FG\_PCT | 6.0% |
| STL | 6.0% | FG\_PCT | 3.1% | FG3A | 3.5% |
| BLK | 5.5% | AST | 2.7% | MIN | 3.4% |
| AST | 5.4% | FG3A | 2.3% | PF | 3.1% |
| PLUS\_MINUS | 4.6% | FTA | 2.1% | DREB | 1.7% |
| FTA | 4.3% | PFD | 1.9% | BLKA | 1.5% |
| FG3\_PCT | 4.0% | OREB | 1.9% | AST | 0.9% |
| OREB | 3.7% | STL | 1.9% | FGM | 0.7% |
| PFD | 3.6% | FG3\_PCT | 1.7% | BLK | 0.6% |
| PER | 3.1% | FGM | 1.7% | TOV | 0.5% |
| MIN | 2.7% | TOV | 1.6% | FTA | 0.3% |
| DD2 | 2.1% | FT\_PCT | 1.3% | PFD | 0.2% |
| FG3A | 1.5% | BLKA | 1.2% | OREB | 0.2% |
| PIE | 1.0% | BLK | 1.2% | FT\_PCT | 0.2% |
| TOV | 0.9% | FG3M | 0.8% | TD3 | 0.0% |
| BLKA | 0.6% | DD2 | 0.1% | STL | 0.0% |
| PF | 0.0% | TD3 | 0.0% | DD2 | 0.0% |

Figure 13 Model Feature Importance

### Phase 2: Player Selection

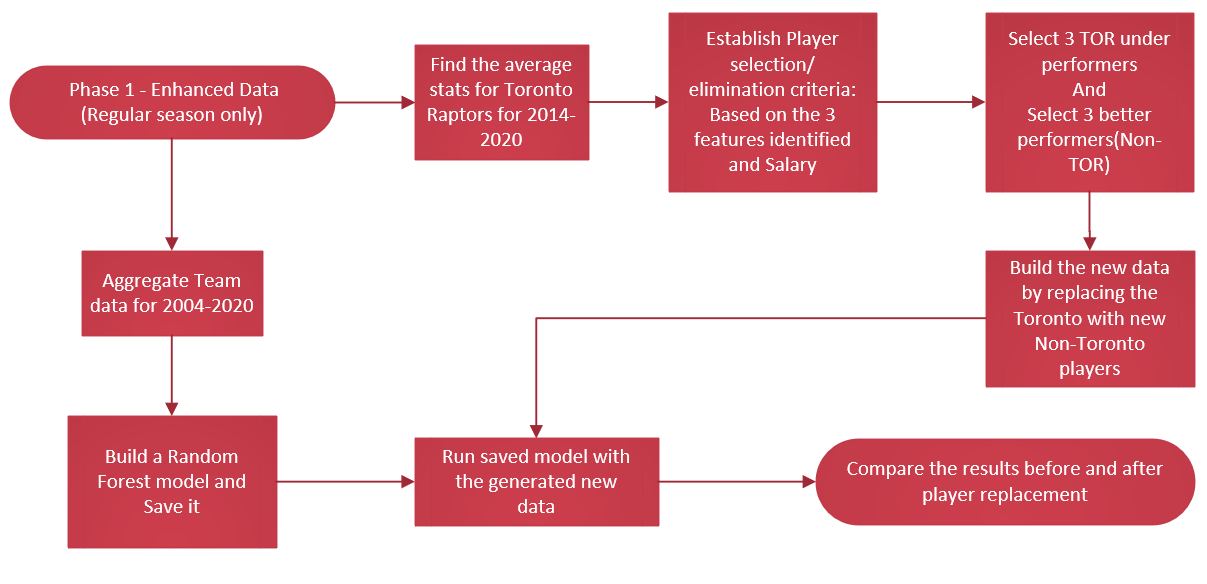


Figure 14 Process for Phase 2: Player Selection

In preparation of showing Team Win improvements the transformed data from Phase 1 was aggregated to the team/game level for the entire dataset (EDS file) and for one regular season (ORS file) for 2019-2020. The EDS file was processed in the same way as the we did for the initial PlayerGameLogs data where we only focused on the Random Forest to develop our Team Wins Prediction model.

The ORS file was adjusted to remove 3 of the least useful/used Toronto players with the selected 3 potential non-Toronto players based on PLUS\_MINUS, PIE, PER, and Salary criteria (Figure [*Figure 15 TOR and Non-TOR Player Average Stats Comparison*])

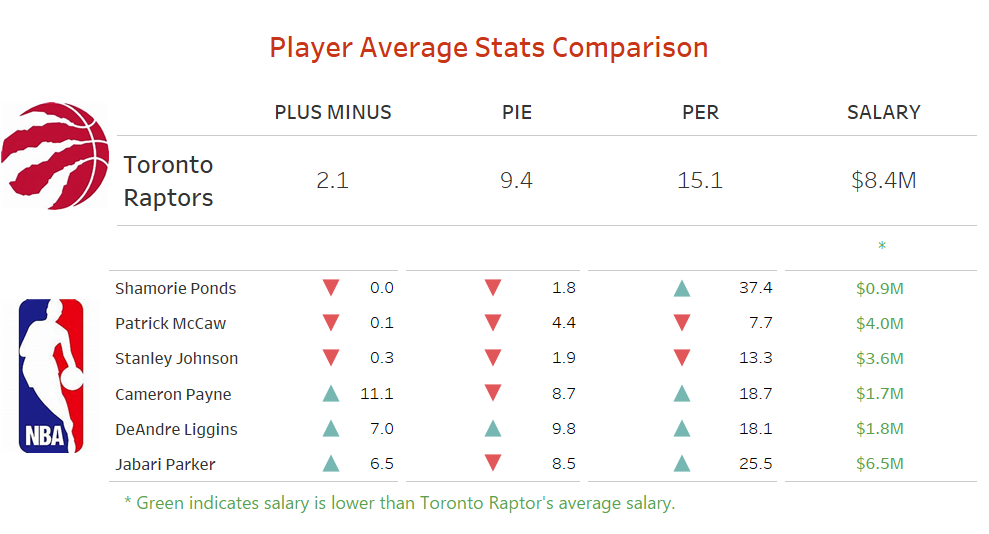
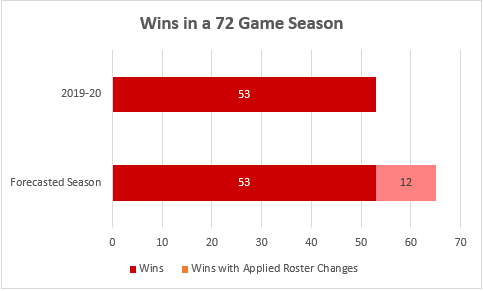


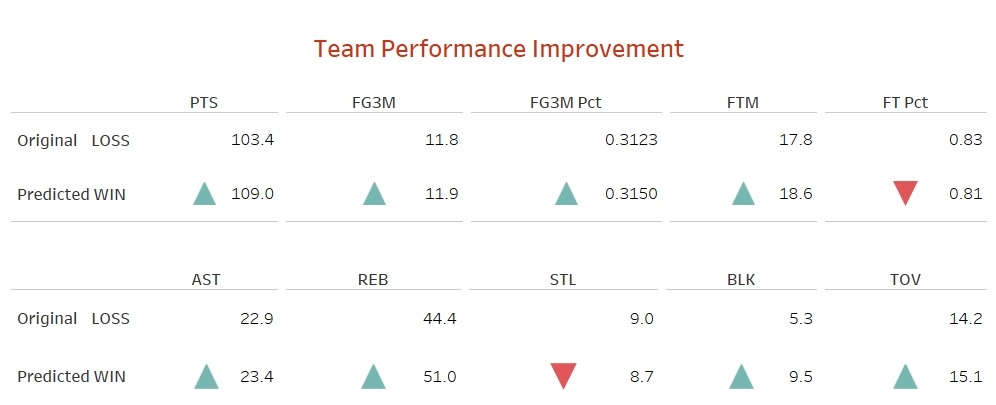
Figure 15 TOR and Non-TOR Player Average Stats Comparison

The model developed from the EDS file was applied to predict the Win/Loss (WL) of the modified ORS file.

# results

From our model analysis we forecast an improvement of 22.6% or 12 wins in a 72-game regular season.





# Conclusions

### Recommendations

1. The primary objective of this analysis is to determine which features are important to the Toronto Raptors team to produce more wins in the regular season and the playoffs.
2. The secondary objective is to review team players’ performance-to-cost effectiveness.

[*Show list of names in a table for replacement and team averages before and after replacement*]

PER, PIE and PLUS\_MINUS are the most contributing factors for how much value a player is adding to the team. A player with a high field goal % and 3-pointer % expectedly contributed heavily in the team.

* For improvements to the Toronto Raptors’ roster the organization is to look at non-Toronto players with higher values in PLUS\_MINUS, PER, and PIE compared to their current roster. These hold potential values in producing team Wins at and are under utilized by their current teams.

There is one player that is currently selected to be replaced on the Toronto roster. Ponds who is new to the roster with only 4 regular season games is seen as a low value player in terms of PLUS\_MINUS and PIE but has a very high PER. This mainly is due to a lack of usage, but additional data is required.

* This player has an extremely high PER but has not been on the court a lot. The skills of this player should be either explored or the player should be traded.
* Advanced stats such as PIE and PER are important to understand the complex player performance by an amalgamation of different matrixes. Even then, at times, you would see a player with high numbers because on underutilization.

### Limitations

This analysis is limited to Toronto Raptors only. As the teams change, the features important for those teams can sway. There are some factors which affect performance of a player and are hard to predict such as:

* The player’s rapport with the team.
* The player being satisfied with the coaching.
* The placement in the games.
* The player’s happiness with the contract.
* Personal life

# References

Bleacher Report, Inc. (2021). *Advanced NBA Stats for Dummies: How to Understand the New Hoops Math*. Retrieved from bleacherreport.com: https://bleacherreport.com/articles/1813902-advanced-nba-stats-for-dummies-how-to-understand-the-new-hoops-math

ESPN. (2020-2021). *NBA Player Salaries 2020-2021*. Retrieved from ESPN.com: http://www.espn.com/nba/salaries

HoopsHype. (2020-2021). *NBA Player Salaries*. Retrieved from hoopshype.com: https://hoopshype.com/salaries/players/

Jee, K. (2019, December 22). *How to Get NBA Data Using the nba\_api Python Module (Beginner).* Retrieved from Playing Numbers: https://www.playingnumbers.com/2019/12/how-to-get-nba-data-using-the-nba\_api-python-module-beginner/

NBA Media Ventures, LLC. (2021). *NBA Advanced Stats*. Retrieved from NBA.com: https://www.nba.com/stats/

NBA Media Ventures, LLC. (2021). *NBA Advanced Stats - Glossary*. Retrieved from nba.com: https://www.nba.com/stats/help/glossary/

Patel, S. (2020, August 19). *swar / nba\_api.* Retrieved from GitHub: https://github.com/swar/nba\_api/blob/master/docs/table\_of\_contents.md

SportRac. (2021). *Toronto Raptors 2020 Salary Cap*. Retrieved from spotrac.com: https://www.spotrac.com/nba/toronto-raptors/cap/

Sports Reference. (2020-2021). *2020-21 NBA Player Contracts*. Retrieved from Basketball Reference: https://www.basketball-reference.com/contracts/players.html

Sports Reference. (2020-2021). *Basketball Reference*. Retrieved from Basketball Reference: https://www.basketball-reference.com/