

NFL Tendency Analysis and Basic Play Type Prediction

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Introduction:

Motivation

Growing up with an avid sports fan as a father, I've been watching, playing, and following sports for as long as I remember. In his younger years my dad also worked as an engineer. As a child, my dad was obviously the coolest person in the world to me and I wanted to be just like him, so naturally I developed a keen interest in mathematics and engineering. It was inevitable that these two childhood passions would get entangled with one another. It first began with a simple understanding of the game of football and pattern recognition. From watching enough NFL games, I was able to begin to understand the tendencies of play calls during different parts of the game. Thereafter, I quickly became a 'backseat' coach, shouting at the TV when a coordinator made what was in my opinion a poor play call.

Growing up in Chicago, I am naturally a Bears fan and through most of my time following them, they have been a run heavy team. This can be particularly frustrating as I've witnessed many 4th quarter loses because of conservative playing calling on offense and relying on the defense to hold. From my perspective, it seemed that everyone knew the Bears would run the ball if it was the 4th quarter and they had any sort of lead. It was irritating that the play-callers wouldn't take advantage of this by trying to run something more aggressive and unexpected. As I've gotten older, I realized that my mind might be biased as I might only be recalling instances where the play calling seemed stale. This inspired me to want to empirically quantify what play calling tendencies truly look like in the NFL and to see if some machine learning methods could be utilized to predict play calls.

Today, with the availability of data and my experience in programming, I no longer have to settle for the anecdotal evidence/data gained from my years of watching the NFL. Like a child with a new toy, below I dive into an NFL play by play dataset that I was able to acquire online.

Analysis Overview:

The intent of this study is to empirically quantify the offensive play calling tendencies of the NFL at the aggregate and team levels. In particular, the ratio of run vs pass calls at both levels are quantified in general as well as being quantified subject to other important game variables. Similarly, the relative ratios of the play direction at the team level is quantified to provide insight on how specific teams spread the ball across the field. After these descriptive analyses, a predictive approach for playing is performed. Namely, a XGBoost model is developed to predict the most basic aspect of a play call; namely will the possession team call a run or pass at any given instance of time in a football game. Lastly another descriptive analysis is performed to

motivate the use of this data at the player level for future studies. In particular, the offensive impact on the Denver Broncos due to acquiring Peyton Manning is explored.

Analysis Outcomes & Implications:

The information generated from the tendency analyses as well as the predictive model can provide significant advantage in both offensive and defensive strategies in the NFL. It can help defenses to better prepare and predict their opponents moves while on the flip-side of the token such information can provide visibility to offensives on how they could diversify their play selection. The player analysis segment provides a means to gauge how player acquisitions or trades are paying off for a given team. It can also shed light on what combinations of offensive players being on the field at the same time provides the maximum offensive efficiency for a given team. Much of the analyses contained within this report serve to also motivate deeper dives into this dataset.

Basic Football Terminology:

Prior to discussing the dataset in further detail, a quick run-down of relevant football terminology will be useful in interpreting the discussion as well as the predictive model.

- Down: The team in possession of the football has a limited number of downs (four in the NFL) to advance ten yards or more towards their opponent's goal line. If the team is unable to progress the ball ten yards in four downs, the ball is given over to the opponent. Teams also have the option to punt the ball on the 4th down if they do not think they can gain the yards left.
- Yard-line: A football field consists of 100 yards. There is a hash mark at each yard and at every 10 yards there a number painted representing the yard-line. From one end, the yard-line count starts at 0 until midfield which is the 50 yard-line. However, as a team passes the 50 yard-line, the count begins to go from the 50 yard-line down to the 0 yard-line. Figure 1 below depicts this visually
- Pass vs Run play: A pass play is when the ball is thrown in the air to progress the ball forward versus a run play is when the ball is handed-off (or kept by the quarterback) and is attempted to be moved upfield by running.
- Shotgun: In the shotgun, instead of the quarterback receiving the snap from center at the line of scrimmage, he stands farther behind the line of scrimmage.

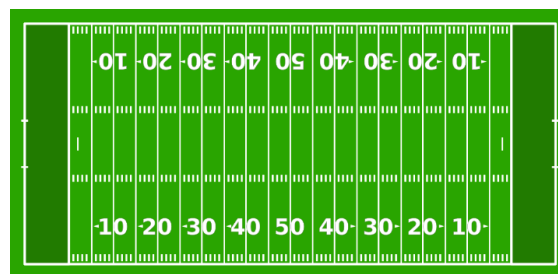


Figure 1. NFL Football Field Representation

The Data:

The dataset considered in this study contains all NFL plays called between the 2009-2018 seasons. The dataset was acquired from Kaggle:

<https://www.kaggle.com/maxhorowitz/nflplaybyplay2009to2016>. Each play is broken down into significant detail containing information on the game situation, players involved, play result, etc. For this analysis, the dataset is reduced via filtering and cleaning steps to attain a subset containing information for general play call selection.

Table 1. Sample of Dataset

game_date	yardline_100	half_seconds_remaining	game_seconds_remaining	down	dstogo	play_type	yards_gained	posteam	shotgun	score_differential	desc
2016-10-09	70.0	93.0	1893.0	2	5	pass	9.0	BUF	1	0.0	(1:33) (Shotgun) T.Taylor pass short right to ...
2016-09-25	84.0	42.0	42.0	1	10	pass	10.0	MIA	0	1.0	(:42) R.Tannehill pass short right to D.Sims t...
2014-10-12	20.0	1399.0	1399.0	2	14	pass	2.0	DET	1	10.0	(8:19) (Shotgun) M.Stafford pass short right t...
2010-01-03	79.0	251.0	251.0	2	7	run	4.0	MIN	0	37.0	(4:11) A.Young left end to MIN 25 for 4 yards ...
2011-09-18	16.0	792.0	792.0	1	10	pass	0.0	MIA	1	-6.0	(13:12) (No Huddle, Shotgun) C.Henne pass

A description of each of the columns is as follows:

- **game_date**: simply the date of the game corresponding to the given data row
- **yardline_100**: This field was generated to improve interpretability of field position for a machine/computer. The value is set to where a team is on the field between 0 – 100. For example, a value of 80 would mean you are on the opponent's 20 yard-line or 20 yards away from the goal-line the team is trying to score at
- **half_seconds_remaining**: number of seconds remaining in the half
- **game_seconds_remaning**: number of seconds remaining in the full game
- **down**: the down number (1-4). See previous section for explanation of what a down is
- **play_type**: indicates if the play that was called was either a run or a pass
- **yards_gained**: states how many yards were gained as a result of the play
- **posteam**: Name of the team who ran the given play
- **shotgun**: a binary flag to represent if the play that run was in the shotgun formation
- **score_differential**: the difference in score between the two teams at the time when the given play was ran
- **desc**: a text description of the play that was run

Tendency Analysis:

Pass vs Run Tendencies

This is where we dig into the details of play call tendency. To begin with, we take a quick look at the number of pass plays vs the number of run plays called through the 2009-2018 NFL seasons.

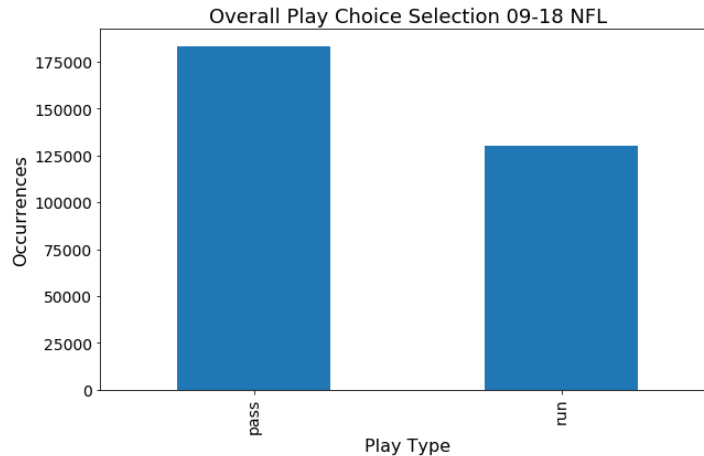


Figure 2. Pass vs Run Play Selection 2009-2018 NFL Seasons

It is evident that there are a lot more pass plays called than run plays. A question that follows is how do the yards gained on pass plays compare to that gained on run plays. From this same dataset, the average yards gained per pass is roughly 6.3 yards versus 4.3 gained per run. Intuitively this makes sense as throwing a ball in the air to a teammate is likely to gain more yards if successful than trying to run the ball through a stream of defenders.

However, it is important to note the rest of the summary statistics. Namely, the median yards gained are 4 per pass vs 3 per run, and the 25th percentile value are 0 and 1 yards gained for pass and run respectively. This is likely because while passing plays have higher potential to gain a lot of yards, they also can go incomplete, resulting in no yards gained. This supports the notion that both aspects of the game and a diversity in play calling are necessary to progress the ball forward towards the opponent's goal-line.

For someone familiar to the game of football it is tribal knowledge that the play type called is related to the down. For instance, on first down, a run play is often called so that a few yards can be gained making the goal for second down shorter allowing for a more versatile set of playing calling options. Figure 3 below shows the tendencies of type of play called per down.

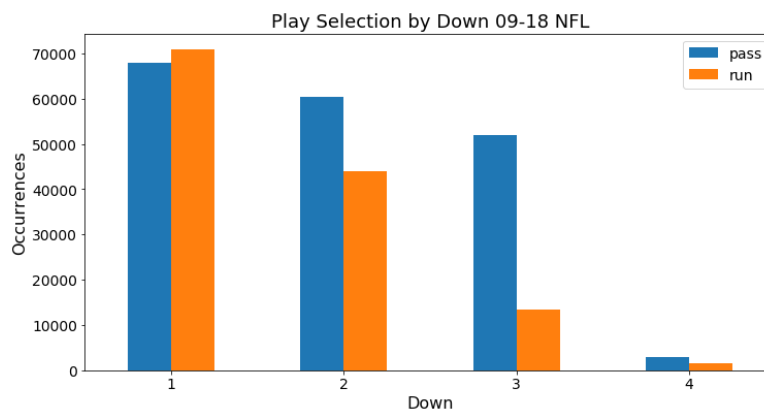


Figure 3. Pass vs Run Play Selection per Down

As the down increases, the number of pass calls in relation to run calls increase significantly. This is somewhat expected behavior as if you are in a 3rd down situation and have a significant number of yards to gain, the best chance to get the yards is through the air. This brings forth the question, how does the play selection relate to the down in combination with the yards left to gain.

Table 2. Pass vs Run Play Selection as a Function of Down & Yards to Gain

		pass_call_percent	run_call_percent
down	yards_to_go		
1	1-3	30.52%	69.48%
	4-6	41.18%	58.82%
	7-10	48.94%	51.06%
	11-19	59.79%	40.21%
	20+	69.30%	30.70%
2	1-3	36.87%	63.13%
	4-6	51.36%	48.64%
	7-10	62.50%	37.50%
	11-19	73.80%	26.20%
	20+	73.81%	26.19%
3	1-3	55.27%	44.73%
	4-6	87.86%	12.14%
	7-10	90.19%	9.81%
	11-19	86.60%	13.40%
	20+	78.42%	21.58%
4	1-3	46.01%	53.99%
	4-6	87.47%	12.53%
	7-10	89.24%	10.76%
	11-19	91.11%	8.89%
	20+	90.53%	9.47%

This table contains significant information for both a team playing offense and defensive. Namely, for the defensive it provides empirical evidence for the likelihood of whether a pass or run will be called at a given down and yards to go situation. Much of this is anecdotally known by most who follow the game closely, but empirical data can confirm or deny the assumptions drawn from anecdotal knowledge and it is much more precise. Furthermore, for a team possessing the ball, it provides areas where one can run an 'unexpected' play call to surprise the opposing defense. For instance, let's consider the example of 3rd down and 4-6 yards to go. 88% of the time, a pass play is called; meaning a defensive will be playing a pass coverage scheme.

Let's see what the data says for yards gained for each type of play called in this scenario. Keep in mind that there is a skew between the play types (88% vs 12% pass, run) that impact the statistical values discussed. The resulting analysis shows that in this scenario on average a pass play yields approximately 5.46 yards while a run play yields approximately 5.44 yards. The median yards gained are 1 and 4 yards for pass and run respectively, again likely due to the

number of passes that go incomplete (0 yards). This simple analysis does not consider many other game factors, but it shows the potential of using this tendency analysis to run unconventional play calls to counteract the defense, which is likely playing off expected anecdotal or data driven tendencies.

As with all things, the game of football evolves over-time. As such another interesting piece of information to study is how the ratio of pass to run plays changes over time. Figure 4 displays this information overlaid with the average number of points scored by team per game, which serves as a proxy for total points scored in that season.

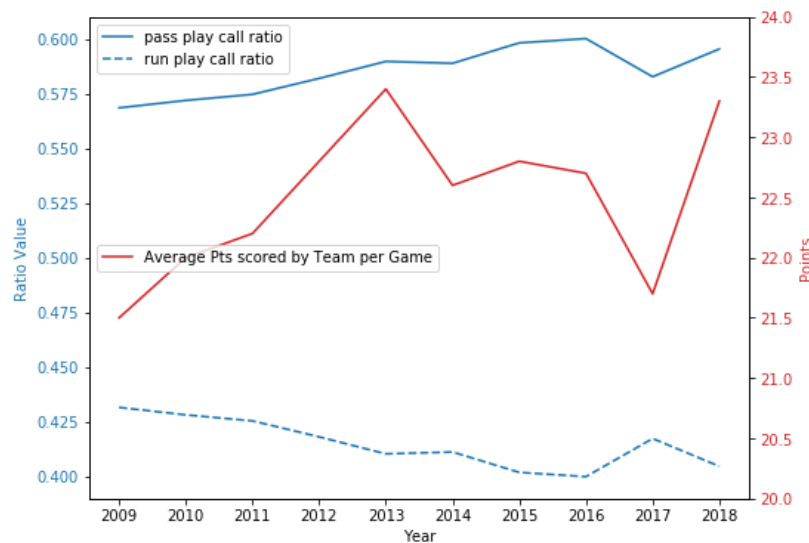


Figure 4. Analysis of Play Selection Over Time

It is interesting to see the relationship between points scored and pass play call ratio. Namely, the data shows that there may be a positive relationship between the trend of the ratio of pass plays to points scored. This could be further explored in more granularity, but it is not pursued in this analysis.

Play Direction Tendencies

Now that we've explored the pass versus run tendencies, it would be valuable to also tie in the direction of the play and see if we can diagnose tendencies at the team level. As done previously, a league-wide (all teams) analysis is performed with the results visualized in Figure 5.

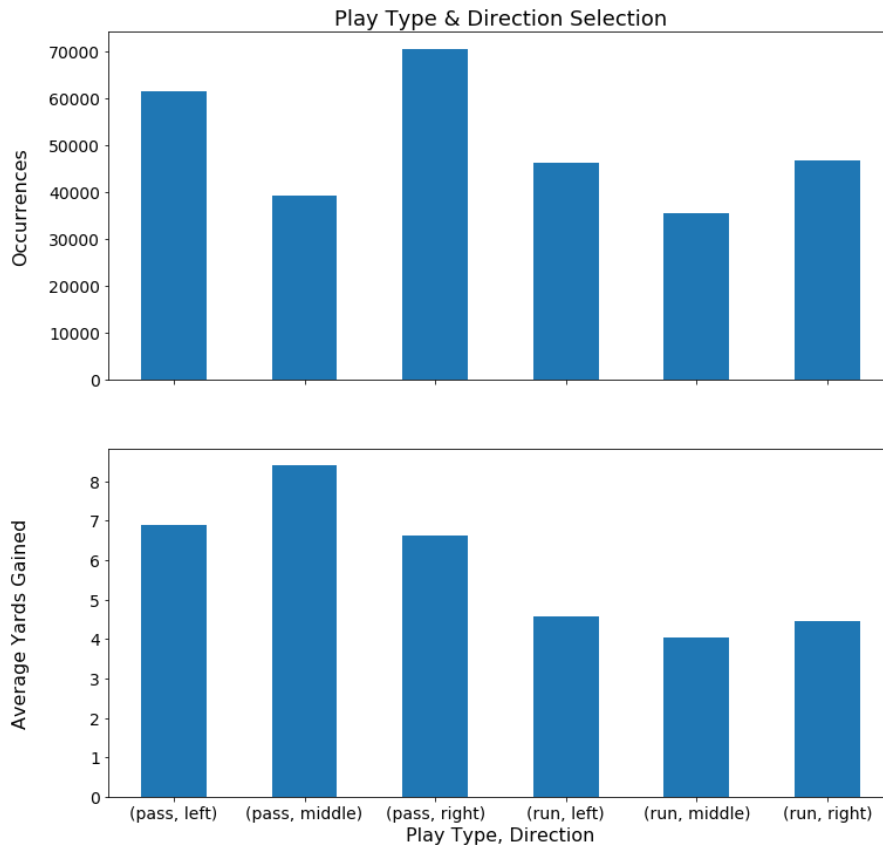


Figure 5. Play Direction Tendencies and Yards Gained

From Figure 5, play calls in the middle (laterally) of the field seem to be the least popular selection. Based on my understanding of the game, I would speculate that this is because the defensive is generally stacked highest in the middle thus running would require going through the greatest number of bodies in this direction and with a pass play there is the least amount of open real estate between defenders to throw the ball in the middle of the field. However, successfully completing a pass in the middle also yields the highest average yards gained. A reason for this could be that catching the ball in the middle of the field leaves a receiver with the largest selection of directions to run after catching the ball.

Team Level Tendencies

An analysis of team by team could be very useful for a defensive coordinator in that he/she would possess the tendencies of a given team to play the ball in a specific direction and the tendencies for that team to call a run or pass play. This would allow a coordinator to set-up his defensive as to counteract these tendencies. Table 3 below outlines the percent of plays that are in a specific direction for each given team during the 2018 season.

Table 3. Team Level Tendencies in 2018 NFL Season

posteam	pass_percent	run_percent
ARI	62%	38%
ATL	61%	39%
BAL	59%	41%
BUF	55%	45%
CAR	54%	46%
CHI	58%	42%
CIN	57%	43%
CLE	60%	40%
DAL	58%	42%
DEN	58%	42%
DET	64%	36%
GB	60%	40%
HOU	56%	44%
IND	62%	38%
JAX	59%	41%
KC	56%	44%
LAC	59%	41%
LAR	59%	41%
MIA	59%	41%
MIN	57%	43%
NE	59%	41%
NO	62%	38%
NYG	60%	40%
NYJ	54%	46%
OAK	60%	40%
PHI	59%	41%
PIT	60%	40%
SEA	54%	46%
SF	56%	44%
TB	60%	40%
TEN	57%	43%
WAS	59%	41%

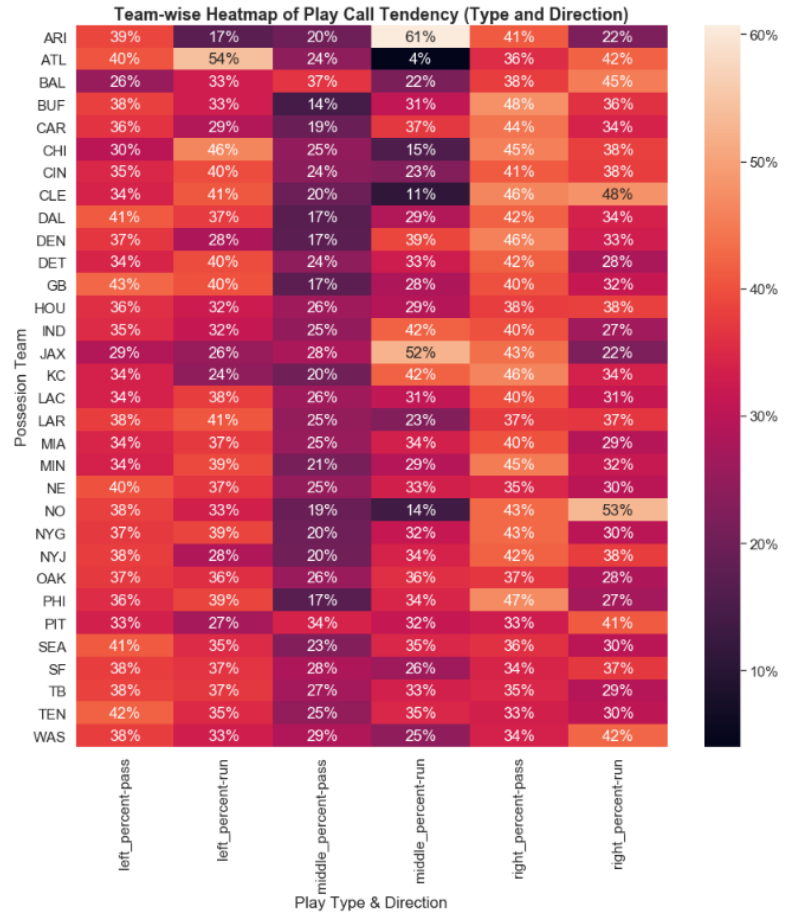


Table 3 and the supporting heatmap can essentially be used as a cheat sheet by both defensive and offensive coordinator. It can be easily updated in real-time with 2019 statistics. For instance if you are a defensive coordinator and your matchup this week is against the Atlanta Falcons, you can use the table above to understand that they are a pass heavy team (61% pass plays) and they tend to throw the ball to the sides rather than the middle (only 24% of throws in the middle). Furthermore, if you suspect they are going to run on a given play, the table above shows they are highly unlikely to run it down the middle (4% of runs). On the flipside if you are the Atlanta offensive coordinator, you can use this information to understand how you are spreading the ball and begin to diversify your play call to avoid the traps the defense might be setting up based on your previous tendencies.

Pass vs Run Play Prediction:

Approach

A machine learning application for this dataset is to utilize historical data to try to predict if a specific team is going to call a pass or run play at any given time during a current game. In this case, the problem is formulated to predict pass or run, thus one can attempt to train a binary

classification model. After trying a few different approaches ranging from logistic regression to ensemble methods, I settled on a gradient boosted tree model (XGboost) for the final model. In a nutshell, a gradient boosted tree model is chain of decision trees that are trained in a gradual, additive, and sequential manner. Each new tree built tries to improve a bit upon the error propagating from the rest of the chain upstream. There are many resources available online for understanding gradient boosting in more depth and to understand the XGboost package/approach.

Model Development & Performance

i) Data subset utilized

To develop this model data from the 2015-2017 NFL seasons were utilized as the training set while the test set was the 2018 NFL data. Pre-2015 data was not utilized as rosters, coaching staff, and other evolutions of the team and game occur so frequently that to predict the 2018 season data, it is best to utilize recent season data.

ii) Feature Engineering

The features fed into the model can be found in Figure 7 below. A fair level of data cleaning had to be performed prior to the tendency analysis. Some examples include accounting for team name changes, removing kicking plays or extra point plays, removing plays where a penalty occurred, etc. Numerical encoding was performed on categorical features as the XGBoost package utilized does not accept string inputs (but in theory most tree models can accept string inputs). In the feature set, the possession team was label encoded, while the response variable (the “play_type” field) also had to be numerically encoded. Specifically, a 0 represents a run play while a 1 represents a pass play.

iii) Model Tuning

Little model tuning was ultimately performed as a randomized grid search showed minimal improvements when testing hyperparameter combinations relative to the defaults in the XGboost python package. In specific, the random grid search was given the following ranges:

```
param_dist = {'n_estimators': [100,200,300],
              'learning_rate': [0.01,0.05,0.1,0.5,1.0],
              'subsample': [0.3,0.5,0.6,0.7,0.9],
              'max_depth': [3,4,5,6,8],
              'colsample_bytree': [0.5,0.6,0.7,0.8,0.9], 'min_child_weight': [1, 2, 3, 4]}
```

There 5 folds fit for 25 different sets of the hyperparameters above resulting 125 total fits. The final model performance is detailed below. Feature importance for this model is also detailed below.

	precision	recall	f1-score	support
0	0.68	0.62	0.65	11710
1	0.76	0.80	0.78	17237
accuracy			0.73	28947
macro avg	0.72	0.71	0.71	28947
weighted avg	0.72	0.73	0.72	28947

Figure 6. XGBoost Classifier Classification Report

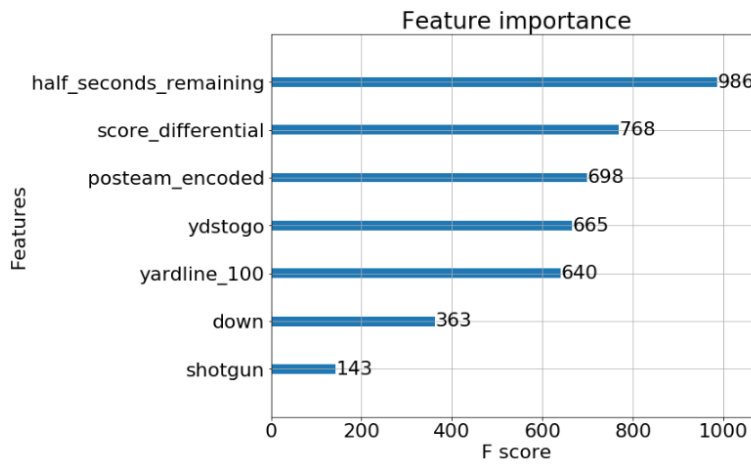


Figure 7. XGBoost Feature Importance

The model achieves a respectable 73% accuracy (with F1 score being in a similar neighborhood) of being able to predict whether a play will be a run or pass play at any given instance of an NFL game. Adding this model to a defensive coordinators toolbelt could provide further information to optimize defensive schemes against any given opponent. Of course, the model could be even more useful if it could predict further details such as the specific type of play that might be called such as a screen play, fly route, sweep to the right, etc. Unfortunately, this level of detailed information was not readily available to parse through. However, based on the data already being collected by the NFL, it is highly likely this may be available elsewhere online.

There are some interesting notes from the feature importance plot. The seconds remaining in the half is the strongest parameter followed by the score differential. From domain knowledge, an explanation for this could be that deep field passes are more often seen when the time is running low (in either half) and/or when the possession team is significantly behind in the score. It is also of interest that the possession team is a strong feature as it supports the notion that studying analytics and tendencies of the team you will be playing against can considerably improve your chances to win by preparing appropriate defensive schemes.

Player Level Analysis:

This dataset can also allow for analyzing a given player's impact on a team or game. A quick study performed here is to show how the Denver Broncos offense dramatically improved when they signed Peyton Manning. The three years prior to Peyton joining the team are compared to the three years that he was the starting QB.

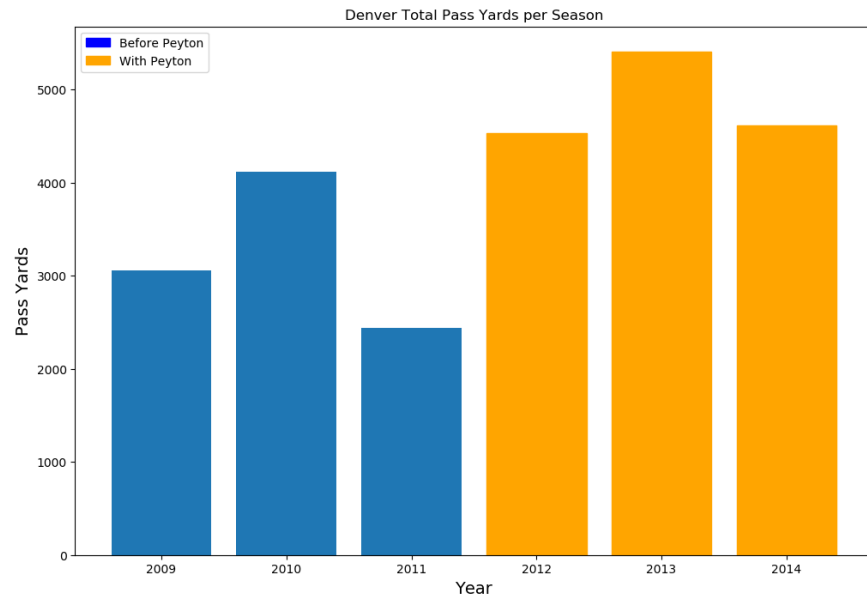


Figure 8. Peyton Manning Impact on Denver Broncos Total Pass Yards

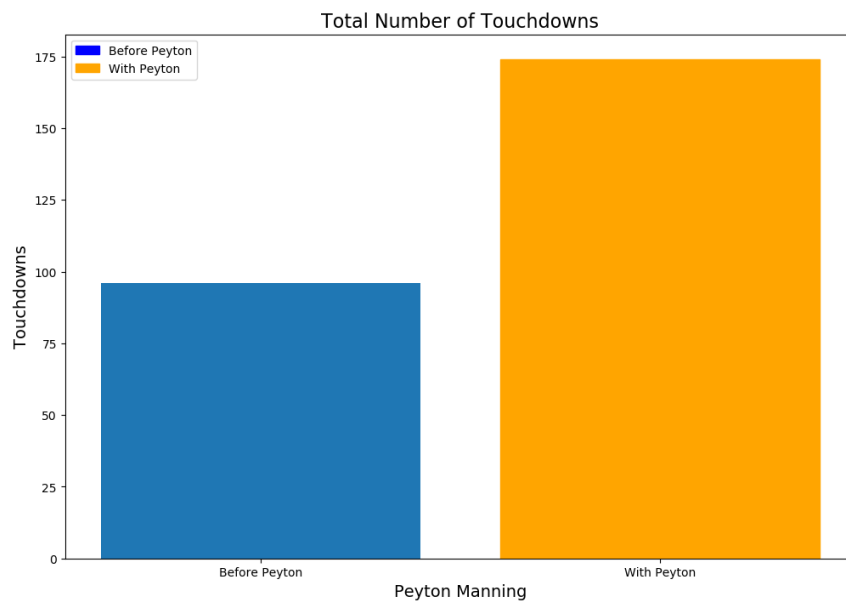


Figure 9. Peyton Manning Impact on Denver Broncos Touchdowns

From the above figures, it is clear to see that the Broncos dramatically improved their offensive prowess after adding Peyton Manning to their roster. They gained more yards per game, scored more points per game, and had more possession time per game. This is reflected in their win-loss statistics through these seasons. Namely from 2009-2011 they had 20 wins and 28 losses while from 2012-2014 they had 37 wins and 11 losses. While all of this cannot be attributed to just the addition of Peyton Manning, it is clear that he had a significant impact. This quick analysis shows the potential of utilizing similar and more complex analysis to gauge how player acquisitions/trades are paying off for a given team.

Conclusions:

Performing the analyses contained within this article has served to only deepen my itch to study NFL and sports analytics rather than satisfying it. The analysis performed within this article is just one of many ways to interpret and analyze this dataset. Particularly this information and similar studies can provide significant advantage in both offensive and defensive strategies in the NFL. It can help defenses to better prepare and predict their opponents moves while on the flip-side of the token such information can provide visibility to offensives on how they could diversify their play selection. With football being dubbed a 'game of inches' being able to effectively predict just a few plays could change the course of the entire game. Similar tendency analysis studies can extend to baseball, basketball, etc. For example, such analyses can be used to help fine tune defensive shifts in baseball or to determine what aspects of a batters hitting needs to be worked on such that they can counteract such defensive shifts.

Continued Work:

There is much more that can be done with the dataset discussed in this article. The model was developed over a very short period and was built with a subset of features manually selected based on domain knowledge. A few suggestions for continued work are:

1. Feed the model with many more features and allow it to select what is important
2. Assess model predictive capabilities on different game situations. E.g how does it perform in 1st and 10 yards to go situations versus 2nd and 6 yards to go situations?
3. Collect data on offensive formation (singleback, trips, spread, etc) and perform team level tendency analysis on that as well as adding it as a feature to the predictive model
4. Determine if including recent plays called would improve the prediction capability of a model. E.g. use a time-series prediction method such as LSTM or markov chain approach
5. Generate new features via stronger feature engineering
6. Define a custom target/response variable that may provide a stronger actionable result for users of the model
7. Perform analyses to determine what types of plays each team has the most difficulties defending against

8. Using the personnel data, an analysis could be performed at the team level to understand what types of plays are called when certain players are on the field.
9. Similar to the Broncos and Peyton Manning analysis performed, a specific player's impact on a game can be studied by viewing play selection, yards gained per game, etc. General Managers can utilize such analyses to grade themselves on acquisitions they made or such analyses could be used to better proactively evaluate a player acquisition or release.