Project Title: ESPN NFL Survival Pool Optimization
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Executive Summary

As part of George Mason University’s System Engineering and Operations Research (SEOR) graduate program, students may pursue a Master of Science in Systems Engineering or Master of Science in Operations Research. To satisfy degree requirements, students must take SYST/OR 699, a course serving as a synthesis activity where students complete an applied and realistic project relevant to Systems Engineering and Operations Research.

This Project Report documents the work of SYST/OR 699 students Audrey Barry, Lauren Moore, Adam Patterson, and Dominique Strothers (i.e. Team ESPN) for the Fall 2016 Semester at George Mason University. The Project completed by the students was sponsored by Entertainment and Sports Programming Network (ESPN), and was focused on National Football League (NFL) Survivor Pool contests.

For this Project, Senior ESPN Analyst Brain Burke challenged Team ESPN to explore the concept of NFL Survival Pools, and create a tool facilitating the optimal choices contestants should make when participating in a Survival Pool. The ESPN NFL Survival Pool Optimizer (ENSPO) System was created by Team ESPN for this Project, which proved to be an overall success.

Introduction

Background

The NFL is a professional American football league consisting of 32 teams, and is one of the four major professional sports leagues in North America. The NFL’s 17-week regular season runs from the week after Labor Day to the week after Christmas, with each team playing 16 games and having one bye week. Following the conclusion of the regular season, six teams from each of two conferences advance to the playoffs: a single-elimination tournament culminating in the Super Bowl.

In addition to watching NFL games Thursday, Sunday, and Mondays nights, NFL fans can remain engaged in the NFL season via a number of contests associated with the NFL. In most contests, contestants pay to enter and are given monetary rewards based on performance in the contest. A few common contests include:

- Fantasy Football
- Fanduel Football
- Survivor Streaks
- NFL Pick’em
- NFL Survival Pools
An NFL Survivor Pool is a contest centered on NFL game predictions that takes place during an active NFL regular season. Each week of the regular season, a contestant in a pool chooses 1 team. If that team loses, that contestant is out of the pool for good. If that team wins, the contestant remains in the pool and proceeds to pick a team during the next week of the season. Contestants can only choose a team once per season; if the team chosen by a contestant during a given week wins, the contestant cannot choose that team for the remainder of the season.

Pools can contain any number of contestants. The goal of the contest is to survive the longest in the pool, i.e. be the last contestant standing. Typically, contestants will pay to join the pool and the winner of the contest is awarded the money collected by all contestants.

Contestants must strategize to survive the longest in their pool. Some contestants may simply choose the strongest team each week, which is commonly known as the “greedy” method. Though this may result in a contestant surviving early weeks in a season, a problem with this approach is that a contestant may be left to choose weaker teams later in the season. Alternatively, contestants may have a more conservative approach and save stronger teams for later in a season. This may be imprudent as strong teams do a contestant no good in later weeks of the season, if the contestant is eliminated early due to choosing weak teams.

Contestants must be diligent in strategizing to win an NFL Survivor Pool. The goal of this Project was to explore the concept of NFL Survival Pools and create a tool facilitating the optimal choices contestants should make when participating in an NFL Survival Pool.

Problem Statement
Team ESPN was challenged to create a tool that provides guidance to the problem:

In any given week of the season, what team should an NFL Survival Pool contestant select to optimize their chances of surviving the longest in the pool? How would this strategy compare to common heuristics, such as the “greedy” method of survival?

ESPN currently does not host a service to specifically address these questions. ESPN desires to remain prevalent in the sports industry, and this tool would add to their portfolio of sports analytic services and promote their popularity amongst sports fans.

The Sponsor anticipated to use the tool as the structure for a service that ESPN could provide to NFL Survivor Pool contestants.

Primary Stakeholders
The primary stakeholders for this Project include:
Requirements
The initial requirements for this Project were:

- The team will create an integer optimization model with the goal to maximize the serial probability of winning by surviving longest in an NFL Survival Pool.
- The model shall account for uncertainty regarding the relative strength of each team, both currently and in the future.
- The model will provide a suggested team for any week of the season, given the teams a contestant has already selected.
- The team will work to demonstrate the superiority of the model compared to common heuristics, such as the greedy method.

Work Breakdown Structure & Schedule
The Work Breakdown Structure (WBS) for this Project was broken down into 4 phases, as displayed in Figure 1 - Work Breakdown Structure and further explained in Table 1 - Work Breakdown Structure Description. Work efforts were scheduled in accordance with the major deliverables defined in the syllabus. In addition to milestones for major deliverables, efforts were defined so that milestones could be met in a timely fashion, as illustrated in Figure 2 - Schedule.
Figure 1 - Work Breakdown Structure

Table 1 - Work Breakdown Structure Description

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Problem Investigation

Scoping the Problem
During the initial collaboration with the Sponsor, Team ESPN identified a multitude of factors that could be considered in the problem solution. Following identification of these factors, Team ESPN, with approval from the Sponsor, scoped to problem to incorporate the set of the factors described below.

- Probability of Winning – The probability a team will win a game during a current week and all future weeks would be required when simulating the optimal pick a contestant should choose for any given week. These probabilities would be included for analysis of the Problem, and validation of Problem Solution.

Figure 2 - Schedule
- Previous Team Selections - This value is required as it is a constraint. The optimal path for a contestant in any given week cannot include a team a contestant has chosen in a previous week. The Problem Solution would include this constraint.

- Accounting for Player and Team Ratings - When determining the probability a team will win a game, both individual player ratings and overall team ratings can be considered. Team ESPN committed to research sources of game probabilities, such as Vegas Odds (reference NFL Betting Market / Vegas Odds) which reflected both.

- Uncertainty of Future Weeks - The further away a game is from the current week, the more uncertain the prediction for the outcome of the game. For example, in week 2, the projections for week 17 will not be as accurate as the projections for week 3. Accounting for uncertainty must be included in the Problem Solution.

- Team Consistency - Some NFL teams are historically more predictable than others. For example, some teams may perform before better (or worse) than predictions more often than other teams. Team ESPN would incorporate this factor in the Problem Solution.

- Divisional Games - There are eight divisions in the NFL, and there are four teams within each division. Every team plays the teams within their division twice each year in the regular season. This means 37.5% of all games in the NFL regular season are divisional matchups. Over time, teams likely become more familiar with all the teams in their division, and this can cause rivalries. Team ESPN committed to analyzing division matchups for each team and integrating this analysis in the Problem Solution.

- Dome Effect - The Sponsor suggested that teams with dome (indoor) stadiums have a difficult time playing in cold climates in December. Team ESPN agreed to factor this into the Problem Solution.

- Pool Size/Pool Strength - Contestants don’t necessarily need to strategize to survive until the end of the season, contestants just need to survive longer than their opponents. The different dynamics of being in a small pool vs being in a large pool are significant when strategizing in an NFL Survival Pool. In the first scenario, contestants have less opponents, therefore may not need to survive long into the season to win. In a larger pool, it is not as clear how long a contestant must survive to win, therefore contestants would likely want to strategize to survive late into the season to win. Furthermore, some pools may have contestants who are very knowledgeable about the NFL or alternatively, contestants who are not well-educated about the NFL. The probability that contestants survive through each week in the former case is likely higher than that of the latter. This probability is known as Pool Strength. Team ESPN implemented the Problem Solution such that different results
would be provided by the Problem Solution based on the size and strength of a contestant’s pool.

Initial Research
One of the initial steps in solidifying the Problem Solution was to investigate methods to derive weekly game probabilities. These probabilities would be required to validate the model as well as to provide a baseline to determine how the model would account for Player and Team Ratings, Uncertainty of Future Weeks, the Dome Effect, Team Consistency, and Divisional Games.

Team ESPN conducted research on methods to derive probabilities, and what sources the team would use for these probabilities. These methods/sources are described in subsequent sections.

NFL Betting Market / Vegas Odds
Betting on NFL games is a popular gambling practice. NFL betting involves predicting game results and placing a wager on the outcome. “Betting lines” are provided to guide NFL bettors on what games to bet on, and are offered as Point Spreads, Moneyline Odds, and Total Wager.

- **Point Spread** - Includes a numerical value and a favorite team. For example, suppose team A is favorites over team B, and the Point Spread is -10. This means team A is expected to win by 10 points. A bet on A pays only if A wins by at least 11 points while a wager on team B pays only if B either wins or loses by fewer than 10 points. If A wins by exactly 10 points then wagers are usually refunded. (Sportsbook)

- **Moneyline odds** - Includes a positive or negative monetary value and a favorite team. For example, for a particular game, the odds are +140 in favor of one team. The +140 means that for every $100 you wager you will win $140. You do not have to wager $100. The betting line is a payout ratio odds and will be scaled to your actual wager. An example with negative odds would be if the favorite is denoted by the -160, you have to risk $160 to win $100. (Sportsbook)

- **Total Wager** - Includes a single integer representing the total score of a game i.e. the sum of each team’s points. Bettors bet either over or under on the Total Score at the end of the game of the combined teams. For example, consider the betting line for the Total Wager is 33. For you to win the final score would have to be 34 points combined for both teams. If the total score is exactly 33 then your wager would be returned to you. If the total score is less than 33, you would lose your wage. (Sportsbook)
Of these betting lines, Point Spreads provide the most straightforward predictions for game outcomes. The Las Vegas sports books, i.e. Vegas Odds, dominate the NFL betting market. Vegas Odds offer opening Point Spreads on the coming week's game, and closing spreads which are locked in at the end of each week. (Sportsbook) The limitation of Vegas Odds is that they do not provide predictions for future weeks, so they could not serve as the sole source of game predictions in the development of the Problem Solution. Team ESPN performed significant review of academic literature related to the Vegas Odds, as explained in Literature Review, and identified Vegas Odds as a robust source of game predictions for the current week. Furthermore, Team ESPN made the assumption that the Vegas Odds incorporate both Player and Team ratings, as Vegas bookmakers create spreads week by week, hence incorporating recent overall team performance and individual player trends.

ESPN NFL Power Rankings

NFL Power Rankings simply provide the list of the 32 NFL Teams ordered from best to worst. Power Rankings are created based on votes from ESPN's power panel, a group of more than 80 writers, editors and TV personalities (NFL Power Rankings: Preseason edition). These rankings are published week by week by ESPN, and are also available week by week for previous seasons.

As Power Rankings are readily available, Team ESPN sought to find a method to use the rankings to predict future game outcomes. Michael Beouy, a well-known sports data analyst, suggested in his site “unpredictable.com” that Point Spreads for NFL games can be predicted via the difference between the home team’s rank and the away team’s ranks. Furthermore, he suggests using the current and previous week’s ratings when predicting Point Spreads, with more weight put on recent ratings. Beouy uses his own calculations to derive team rankings. Team ESPN chose to incorporate some of his methodology to create game probabilities for future games via use of ESPN’s Weekly NFL Power Rankings (Beouy).

After review of Beouy’s methodologies to create game probabilities, Team ESPN derived a formula to predict future games using NFL Power Rankings:

\[ \text{Point Spread} = \text{Average} \left[ (\text{HTR}_i - \text{ATR}_i - 2.5) \times w_i \right] \]

- \( i \) = \{current week, current week-1, current week-2, current week-3, current week 4\).
- \( \text{HTR}_i \) = Home Team Power Ranking in week i (Note – For weeks 1-4, rankings from the previous season are used)
- \( \text{ATR}_i \) = Away Team Power Ranking in week i (Note – For weeks 1-4, rankings from the previous season are used)
- \( w_i \) = weight given to week i
- For \( i = \) current week: \( w_i = 1 \)
Else: \( w_i = \frac{1}{(\text{current week} - i + 0.4)} \)

**Elo Ratings**

FiveThirtyEight, commonly known as referred to as 538, is a website that focuses on opinion poll analysis, politics, economics, and sports blogging. 538 maintains a continuously updating NFL predictions page that allows you to see the latest rankings, plus win probabilities and Point Spreads for the current week of NFL games. 538 predictions are built on Elo Ratings, a simple system that estimates each team’s skill level using only the final scores and locations of each game. (NFL Elo Ratings Are Back)

538 caveats that their predictions are not as strong as Vegas Odds, as Vegas Odds account for a much wider array of information. With that said, Team ESPN chose to not include 538 methods for predictions of the current week. However, Elo Ratings were used as another source of predicting outcomes for future games. 538 provides a formula to convert Elo Ratings into Point Spreads. (Introducing NFL Elo Ratings)

- **Point Spread** = \(\frac{(\text{Home Team Elo Rating} - \text{Away Team Elo Rating})}{25}\) - 2.5

**SurvivorGrid.com**

Yet another source of game predictions is SurvivorGrid.com. This site was built to help NFL Survivor Pool contestants by providing week by week, current and future game predictions. The site does not provide insight into how their predictions are created, however they are publicly available. (SurvivorGrid.com)

Team ESPN determined that SurvivorGrid.com would be a good additional source for future game predictions when deriving Problem Solution.

**Probability Conversion**

All of the sources researched by Team ESPN provided current and future Point Spreads for NFL games. This led to investigation of methods to convert Point Spreads into probabilities of winning a game that could be used in the Problem Solution.

TeamRankings.com aggregates a vast repository of sports stats and data, publishes this data, and uses the data in sports ratings systems. On this site, the history of Vegas Odds with respect to how accurate they are in measures the actual outcome of NFL game winners is provided, going back through the 2003 season. (NFL Odds History)

Using this history, Team ESPN used linear regression to come up with the following formula to convert Point Spreads to win probabilities: \( \text{Probability of winning} = -0.0293 \times (\text{Point Spread}) + 0.5 \). The \( r^2 \) value for this formula was 0.9675, hence Team ESPN felt confident in using the
formula to convert Point Spread to probabilities. This formula would be used to convert Point Spreads, regardless of the source, into win probabilities within the Problem Solution.

**Figure 3 - Probability Conversion** displays how the Probability of Winning formula was derived from TeamRankings.com data. The x-axis denotes the Point Spread value. The y-axis denotes the percentage of teams who won that were favored to win by the Point Spread from 2003-2015.

**Figure 3 - Probability Conversion**

**Literature Review**

The topic of NFL survivor pools in academic literature is essentially non-existent; however the efficiency of the NFL betting market has been a topic of investigation in the finance literature for over forty years. Primary research has been aimed at identifying inefficiencies that are exploitable for financial gain, which was relevant to this Project as the NFL betting market was identified as a source to be incorporated into predicting the outcomes of NFL games. Overall, the literature suggests that any inefficiencies in the NFL betting market are small and rather transitory.

Team ESPN identified a number of studies that reported that the NFL betting market does not have significant bias or inconsistencies, hence the market provides reasonably strong predictors of game outcomes. Pankoff (1968) was the first to introduce the NFL betting market into academic literature. In his study, it was concluded that based on the market from 1956-1965, the market was efficient and the Point Spread reflected an optimal and unbiased forecast of
game outcomes. Gandar, Zubar, O’Brien, Russo (1988) results did not permit the rejection of the null hypothesis that betting lines are unbiased predictors of game outcomes. Stern (1991) demonstrated the difference between the winning margin and the Point Spread was normally distributed with mean zero and a standard deviation equal to 14; given that the estimated mean equals zero, this study suggests that betting odds have no specific biases. Dare & Macdonald (1996) found little or no evidence against market efficiency in the NFL and college betting markets for regular season games; however there was evidence of biased betting for Super Bowls. Boulier and Stekler (2003) and Song et al. (2007) showed, that in every year from 1994-2001, the betting market correctly predicted the winner of NFL games at least 63% of the time. The average over this time period was about 65%.

In contrast, Team ESPN uncovered studies that did provide insight into potential factors that suggest inaccuracies in the betting market with respect to predicting game outcomes. Sturgeon (1974) found that betting against the previous week’s big winner was profitable. Levitt (2004) looked at all NFL spreads from 1980-2001 and found that home underdogs beat the spread 53.3% of the time. Kochman (2004) exposed that favorites were victims of inflated expectations and Point Spreads based on data from five consecutive seasons ending with the 2003 Superbowl. Paul and Weinbach (2011) concluded betting against big favorites to be profitable and statistically significant. Wever and Aadland (2012) note that wagering on large underdogs from the 1985 through 2010 NFL seasons would have proven to be a profitable approach.

As explained above, several studies suggest the betting market does not have significant bias or inconsistencies. A few studies contradicted this, revealing the potential that the betting market undervalues underdogs. Team ESPN did not find the latter evidence sufficient enough to take these findings into consideration when completing predictive analytics in support of the Problem Definition.

**Problem Solution**

After evaluation of the Problem Statement and conducting background research, Team ESPN collaborated to develop an outline for the Problem Solution. The Team assessed different programming techniques to develop an Integer Optimization Model, including Excel, R, and Python. The Team had to use the open source add on “Open Solver” to overcome some limitations that were found in Excel. R would be utilized by the team as an interface for the user to input the various necessary fields, and output the results from the model. Python was incorporated along with R for its user interface support which Team ESPN believed would enhance the overall Project. Team ESPN decided to use Excel as the foundation for the model, and R/Python as a supplemental tools in the solution as explained below.
The core of the Problem Solution is an Integer Optimization Model built in Excel using the OpenSolver add on and custom Visual Basic for Applications (VBA) modules. The model finds an optimal solution for the objective function:

\[ \text{Objective Function: Maximize } \sum w_{ij}s_{ij} \]

- \( w_{ij} \) = The weight associated with Team \( i \) in Week \( j \) i.e. the probability Team \( i \) wins in Week \( j \).
- \( s_{ij} \) = A binary decision variable (\( \forall s_{ij} \in [0, 1] \)).
  - If \( s_{ij} = 1 \), then Team \( i \) is selected for Week \( j \)
  - \( s_{ij} = 0 \) otherwise
- Subject to the constraints:
  - Each team must only be selected at most once
  - Each week must have only one team selected

Python and R were used to develop the graphical user interface for the Project. R was also used when accounting for Uncertainty of Future Weeks in the Project. More details on these implementations are explained later in this report.

High Level Design
This section provides a high level outline of the Problem Solution, which Team ESPN named the “ESPN NFL Survival Pool Optimizer”, i.e. ENSPO System. The ENSPO System is composed of three primary components.

Graphical User Interface
The Graphical User Interface (GUI), built using Python and R code, provides the ability for a contestant to input information, and view optimization results. The GUI prompts the player for three initial inputs:

- Pool Size: Remaining number of players in the pool.
- Pool Strength: A probability representing the average chance a player in the pool will progress to the next week. This value defaults to .75.
- Number of Previously Selected Teams: An integer representation for the number of Previously Selected Teams the contestant has already chosen in the NFL Survivor Pool and/or can no longer use or does not want to use. This does not have to necessarily equal the number of previous weeks participated in.
  - In some pools, contestants may be able to select a team they have already chosen. If this is the case, a contestant could chose not to input every team they have selected.
Also, a contestant could input a team that they simply do not want to include in their results. For example, a Redskins fan would never want to bet on the Cowboys winning, no matter how strong the Cowboys are. In this case, a contestant could input the Cowboys as a selected team, even though in reality, the contestant has not used them.

- Based on the Number of Previously Selected Teams input, the GUI presents a drop down list of all NFL teams for the Number of Previously Selected Teams identified. As the contestant selects a team it is locked in and removed from the proceeding dropdown list. Once the player has successfully identified all Previously Selected Teams, this information, as well as the Pool Size and Pool Strength, is translated to the Optimization Model described in the subsequent section.

The GUI outputs the following information from the Optimization Model:

- Optimal path from the current week through future weeks, and two alternative paths.
  - Each path will include the probability each choice will win during a specific week.
  - Each path will include week by week cumulative probabilities for surviving until a given week.
- Graphical comparison of paths including the greedy method.

**Optimization Model**

The Optimization Model is the foundation of the Problem Solution. This component solves the Objective Function and generates a list of the teams to choose each week for the remainder of the season primarily via custom, built in VBA functions. At the beginning of each week, Point Spreads for the current week and future weeks are obtained from the Projections Database (reference Projections Database) and adjusted to account for Uncertainty of Future Weeks.

- For this project, an administrator would be required to input projections manually into the model on a week by week basis. Furthermore, an administrator would be required to initiate a custom function developed in R to adjust projections for Uncertainty of Future Weeks (reference Weekly Administration).

After Point Spreads are input and adjusted for Uncertainty of Future Weeks, they are automatically converted to probabilities and adjusted based on Team Consistency, Divisional Games, and the Dome Effect. Finally, using contestant inputs from the GUI (Pool Size, Pool Strength, and Previously Selected Teams) final \( w_{ij} \) values (i.e. the probability a team wins in a specific week) are set and the objective function is solved. In addition to the optimal path, two alternative paths are displayed with different teams selected for the current week. The model also identifies the greedy path, which is computed by simply choosing the team with the highest win probability each week, given past team selections.
Projections Database
The Projections Database (DB) is the base source for weekly game predictions. Team ESPN chose to use Point Spreads as the main component to measure game outcomes. An administrator could choose to use any source of Point Spread desired. Team ESPN chose to use Point Spreads from the Vegas Odds as the measure of game outcomes for the current week. Vegas Odds are only published for the current week, so for future weeks, Team ESPN used a combination of ESPN NFL Power Rankings, Elo Ratings, and SurvivorGrid projections to generate Point Spreads for future weeks. Custom VBA functions were used to facilitate generation of these projections.

Detailed Design
This section outlines how the Problem Solution was implemented to account for:

- Probability of Winning
- Previous Team Selections
- Uncertainty of Future Weeks
- Team Consistency
- Divisional Games
- Dome Effect
- Pool Size

Note: This section does not outline how the Problem Solution incorporates Player vs Team Ratings. Recall that Team ESPN made the assumption that the source of current week game predictions, Vegas Odds, has considered this factor.

Probability of Winning

Implementation
Team ESPN chose to use Point Spreads as the main component to measure game outcomes. In order to validate the Problem Solution, at least one entire seasons worth of week by week game Point Spreads was needed. Team ESPN derived Point Spreads for the 2014 and 2015 seasons. For each season, there is a set of 16 projections beginning in week 1 through week 17. The projections for the current week are derived from the closing Point Spreads published by the Vegas Odds. For all future weeks, Point Spreads are computed using the average of 3 sources:

- NFL Power Rankings – The methodology to create Point Spreads is in explained in *ESPN NFL Power Rankings*.
- Elo Ratings - The methodology to create Point Spreads is in explained in *Elo Ratings*. 
Points Spreads from SurvivorGrid.com

For all sources, including Vegas Odds, Point Spreads are converted to probabilities via the following formula: \(-0.0293 \times \text{(Point Spread)} + 0.5\) (reference Probability Conversion for more information). For future weeks, Point Spreads are adjusted for Uncertainty of Future Weeks, as explained in the Uncertainty of Future Weeks section, before being converted to probabilities.

To illustrate how Point Spreads for the 2014 and 2015 season were derived, consider the Point Spreads for week 1 and week 15 of the 2015 season.

Week 1
- The Point Spread for the current week = Vegas Odds published for the current week, i.e. 2015 week 1
- The Point Spreads for weeks 2-17 = \(\frac{\text{(Point Spread derived via NFL Power Rankings from the current week and previous 4 weeks, i.e. 2015 week 1, and 2014 weeks 18, 17, 16, 15)} + \text{(Point Spread derived via Elo Ratings from the current week, i.e. 2015 week 1)} + \text{(Point Spreads obtained from SurvivorGrid.com)}}}{3}\)

Week 15 projections
- The Point Spread for the current week = Vegas Odds published for the current week, i.e. 2015 week 15
- The Point Spreads for weeks 16-17 = \(\frac{\text{(Point Spread derived via NFL Power Rankings from the current week and previous 4 weeks, i.e. 2016 weeks 15, 14, 13, 12, 11)} + \text{(Point Spread derived via Elo Ratings from the current week, i.e. 2015 week 15)} + \text{(Point Spreads obtained from SurvivorGrid.com)}}}{3}\)

Uncertainty of Future Weeks

**Data Analysis**

Using weekly Point Spreads compiled for the 2014 and 2015 seasons, as explained in the Probability of Winning section, Team ESPN conducted analysis to determine how Point Spreads should be adjusted to account for Uncertainty of Future Weeks. This involved investigating the Point Spreads of the underdogs for future weeks, and comparing them against the closing Vegas odds published for that game.

This data was grouped in categories based on “Weeks Out”, and whether or not the projected underdog stayed an underdog, or the projected underdog became a favorite once the current week was reached. Weeks Out is a count of how far out the week sits from the current week.
For example, if the current week is Week 6, Week 7 is considered 1 Week Out, Week 8 is considered 2 Weeks Out, etc.

These categorizations resulted in 32 Weeks Out categories. For example, in the 2014 season, the current week is Week 2, we look at the underdog projection for the Ravens vs Steelers game in Week 7. As of the current week, the Ravens are projected as the underdog. However, when Week 7 is the current week, we see that the Ravens are now the favorite team in the match up. We have to account for the probability that a projected underdog, may turn to a projected favorite in a matchup. This gives the 32 different Weeks Out categories, 16 Weeks Out for underdogs staying underdogs, and 16 Weeks Out for underdogs which turned to favorites.

Based on these 32 categories, difference between the projections and actuals were found to see how “off” the projected Point Spread was from the actual closing Vegas spreads. The values for projected underdog and stayed underdog contains both positive and negative numbers. These numbers reflect if the underdog became a larger underdog, i.e. if the difference was a positive number, the matchup had a larger Point Spread. If the value was a negative number, then the actual underdog had a smaller Point Spread. For projected underdog turned favorite, these values are large negative numbers because they have to swing the positive Point Spread, to a negative Point Spread, reflecting the team becoming a favorite.

The next step for organizing the uncertainty model was to group like Weeks Out together. For example, if currently in Week 4, Week 5 is One Weeks Out, Week 6 is 2 Weeks Out, etc. Once all the Weeks Out are grouped, they are fitted to the best fit distribution which describes the behavior of the spread differences. It is important to note that each Weeks Out has 2 distributions, one for when an underdog stays an underdog, and one for when an underdog becomes a favorite. Figure 4 - Uncertainty Distributions below summarizes these distribution and their associated parameters. The percentages show the probability of the projected underdog remaining an underdog, or becoming a favorite.
Implementation

To adjust the projected underdogs Point Spreads for uncertainty, each Weeks Out best fit distribution is simulated and the numerical outcome from the simulation adjusts the spread. The following steps outline how this process is executed:

- Find the Current Week in the model to key on where to begin analysis.
- Call each Weeks Out distribution for each of the projected weeks.
- Randomly select a number between 0 and 1. If that number is less than the Probability of Favorite percentage in Figure 4 - Uncertainty Distributions, then simulate the Favorite Weeks Out distribution and report this number. If not, then simulate the Underdog Weeks Out distribution and report this number.
- Run 1000 random numbers through this process. Take the mean from the outputs of the Weeks Out distributions.
- Deliver the mean from the Weeks Out distribution back into the model to adjust the projected Point Spreads accordingly, (whether simulation value is positive or negative).
  - This is done for each underdog each week, based on how many Weeks Out that underdog is.

This adjustment accounts for the uncertainty of not knowing how well a team will perform X number of weeks into the future. Once the model is adjusted for uncertainty, these new Point Spreads are converted to probabilities, as explained in Probability Conversion.
Consistency

Data Analysis
Team ESPN analyzed how accurate Vegas Odds historically forecast the performance of individual teams in order to determine how predictable team outcomes are. To execute this analysis, game outcomes from the 2012, 2013, and 2014 seasons were consolidated, and compared against the associated Point Spread from the Vegas Odds. Team were categorized based on the deviation of the actual game outcome to the Point Spread:

1. Inconsistent - The team seems to rarely meet the spread and no trend occurs
2. Consistently Bad - The team performs worse than spread projections more often than not
3. Consistently Good - The team performs better than spread projections more often than not
4. Consistent - The Point Spread accurately predicts outcomes for the team

Implementation
- The Optimization Model adjusts $w_{ij}$ values based on the consistency category of both teams in a matchup. If the consistency category for two teams is the same, $w_{ij}$ values are not changed. Table 2 - Team Consistency explains how $w_{ij}$ values are adjusted for all other combinations of matchups.
- Note: This manipulation takes places after $w_{ij}$ values are adjusted for Uncertainty of Future Weeks and converted to probabilities.
- Each week, the category of each team potentially changes based on recent game outcomes which are inputted by an administrator (reference Weekly Administration).
  - For example: Based on historical data, the Raiders are categorized as “Consistently Bad”. In the most recent week, the Raiders beat the spread by 21 points. The Raiders could potentially move into a different consistency category based on this outcome.

<table>
<thead>
<tr>
<th>Fav Category</th>
<th>Und Category</th>
<th>Fav Adjusted</th>
<th>Und Adjusted</th>
</tr>
</thead>
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<tr>
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</tr>
<tr>
<td>4</td>
<td>2</td>
<td>+.03</td>
<td>-.03</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>+.03</td>
<td>-.03</td>
</tr>
</tbody>
</table>
Divisional Games

Data Analysis
Team ESPN conducted analysis on how teams in the same division perform against each other, and how performance within divisions compared to Point Spreads from the Vegas Odds. To execute this analysis, divisional game outcomes from the 2012, 2013, and 2014 seasons were consolidated. With these outcomes, the proportion each favorite team won against each underdog team in their division was determined. If a favorite team won \( \leq 66.7\% \), the matchup of the teams was defined as a “Division Rival”.

Implementation
- Within the Optimization Model, if a matchup (current or future matchup) is defined as a “Division Rival”, the associated \( w_{ij} \) values for each team in the matchup are adjusted:
  - \( w_{ij} = (\text{Original } w_{ij} + .5)/2 \)
- Note: This manipulation takes places after \( w_{ij} \) values are adjusted for Uncertainty of Future Weeks, converted to probabilities, and adjusted for Team Consistency.
- Each week, matchups designated as “Division Rivals” potentially change based on recent game outcomes which are input by an administrator (reference Weekly Administration).
  - For example: Based on historical data, the Patriots and Bills are not considered Division Rivals. In the most recent week, the Patriots were projected as the Favorite team, but they lost to the Bills. The model could potentially begin considering the matchup a “Division Rival”, and hence adjust future \( w_{ij} \) values for matchup as explained above.

Dome Effect
Based on recommendation from the Sponsor, the Optimization Model adjusts \( w_{ij} \) values for the last 5 weeks of the regular season for teams whose home stadium is a Dome (i.e. indoors) when playing away in a cold weathered climate.

Implementation
During the last five weeks of a season, \( w_{ij} \) values for Dome Teams playing in a cold weather climate are adjusted:
- If \( w_{ij} > .03 \), then \( w_{ij} = \text{Original } w_{ij} - .03 \)
- Else \( w_{ij} = .0001 \)

The associated \( w_{ij} \) value for the matchup is updated accordingly so that the total probability of each team in the matchup winning the game still equals 1.
Note: This manipulation takes places after \( w_{ij} \) values are adjusted for Uncertainty of Future Weeks, converted to probabilities, adjusted for Team Consistency, and adjusted for Divisional Rivals.

**Pool Size**

**Implementation**

The Optimization Model includes permutation of \( w_{ij} \) values to account for unique aspects of an NFL Survival Pool related to the size of the pool, and strength of the contestants in a pool. The Optimization Model ingests the parameters of Pool Size and Pool Strength from the GUI in order to determine the probability at least one contestant in a pool will survive through the remaining weeks in a season.

These probabilities are created by first finding the probability that zero contestants survive from the current week through all remaining weeks of the season, then subtracting this value from 1. The binomial distribution is utilized to calculate the probability that zero contestants in a pool survive in a week:

\[
\begin{align*}
\text{b}(x; n, P) &= \binom{n}{x} * P^x * (1 - P)^{n-x} \\
x &= 0, n = \text{number of weeks}, P = \text{Pool Strength}_{\text{Pool Size}} \\
1 - \text{b}(x; n, P) &= \text{probability at least one player survives a week.}
\end{align*}
\]

The week at which this value falls below .50 is considered the “tipping point”. For all weeks leading up to this “tipping point”, weights are not adjusted (other than the weight for the current week, which is always slightly heavier than future weeks in order to give the contestant a strong chance of surviving the current week). Following the “tipping point”, weights are decreased in an exponential fashion.

Note: This manipulation takes places after \( w_{ij} \) values are adjusted for Uncertainty of Future Weeks, converted to probabilities, adjusted for Team Consistency, adjusted for Divisional Rivals, adjusted to account for the Dome Effect.

**Previous Team Selections**

**Implementation**

The GUI requires that a contestant identifies the teams they have already selected in their pool, and/or can no longer use or want to use. The Optimization Model ingests this information, and sets the \( w_{ij} \) values for these teams in a manner such that these teams will not be included in any of the output paths. This is the final manipulation of \( w_{ij} \) values that takes place before the objective function is solved.
Validation Methodology

In order to validate the Problem Solution, Team ESPN simulated the ENSPO System against the 2015 season, and compared these results to common heuristics.

For the 2015 season, results using the greedy method were first compiled to serve as the results for the common heuristic, and a baseline to validate the ENSPO model against. This entailed determining how far a contestant would survive by choosing the strongest team each week based on the Vegas Odds for the current week. This would be the favorite team with the highest Point Spread that the contestant has not yet selected. Three different greedy paths are provided.

Team ESPN desired to compare to an additional common heuristic, which was labeled as the “conservative” method. Results for the conservative method simulate a contestant choosing the favorite team with the lowest Point Spread based on the Vegas Odds for the current week that the contestant has not yet selected. Three different “conservative” paths are provided.

To validate Team ESPN’s model, Team ESPN used their defined Projections for the 2015 season (reference Probability of Winning), and generated results for a Survival Pool with an initial size of 100 contestants.

Within the simulations, each path presents the team selected each week, and if that team won (✓) or lost (✗) during that week. The paths display the outcomes through the week where the second loss is encountered. Team ESPN choose to show outcomes through the second loss rather than the first loss for a number of reasons:

- There are outcomes in the NFL that are essentially unpredictable. For example, in Week 2 of the 2015 season, only 37% of teams favored to win actually won. Also, the top 5 teams projected to win based on the Vegas Odds during this week ended up losing. It’s unlikely that any model could have predict these sorts of outcomes.
- Often, contestants in NFL Survival Pools are given a second chance, i.e. they are eliminated after their second lost.
- Some NFL Survival Pools allow contestants to buy back into a pool, meaning if they lose a game, they can re-pay the initial contest fee and rejoin the contest.

2015 Validation
Greedy Path 1 – Contestant eliminated week 2. Ignoring week 2, the contestant is eliminated week 5.
<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team</td>
<td>NE</td>
<td>NO</td>
<td>SEA</td>
<td>GB</td>
<td>KC</td>
</tr>
<tr>
<td>Outcome</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
</tbody>
</table>

Greedy Path 2 – Contestant chose second highest Point Spread in week 2, and is eliminated week 2. Ignoring week 2, the contestant is eliminated week 5.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team</td>
<td>NE</td>
<td>PHI</td>
<td>SEA</td>
<td>GB</td>
<td>KC</td>
</tr>
<tr>
<td>Outcome</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
</tbody>
</table>

Greedy Path 3 – Contestant chose third highest Point Spread in week 2, and is eliminated week 2. Ignoring week 2, the contestant is eliminated week 5.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
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</tr>
</tbody>
</table>

ENSPO Path 1 - Contestant eliminated week 2. Ignoring week 2, the contestant is eliminated week 11.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
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<th>4</th>
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<td>CIN</td>
<td>PIT</td>
<td>PHI</td>
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<tr>
<td>Outcome</td>
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<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
</tbody>
</table>

ENSPO Path 2 - Contestant chose alternative path 1 in week 2 and is eliminated week 2. Ignoring week 2, the contestant is eliminated week 11.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
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<th>4</th>
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<td>✓</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
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</table>
ENSPO Path 3 - Contestant chose alternative path 2 in week 2 and is eliminated week 2. Ignoring week 2, the contestant is eliminated week 11.

<table>
<thead>
<tr>
<th>Week</th>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Conservative Path 1 – Contestant eliminated week 1. Ignoring week 1, the contestant is eliminated week 2.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team</td>
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<td>TEN</td>
</tr>
<tr>
<td>Outcome</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

Conservative Path 2 – Contestant chose second lowest favorite Point Spread in week 1, and is eliminated week 2. Ignoring week 2, the contestant is eliminated week 3.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team</td>
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<td>MIA</td>
</tr>
<tr>
<td>Outcome</td>
<td>✓</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

Conservative Path 3 – Contestant chose third lowest favorite Point Spread in week 2, and is eliminated week 2. Ignoring week 2, the contestant is eliminated week 3.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team</td>
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</tr>
<tr>
<td>Outcome</td>
<td>✓</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

Conservative Paths perform the worst by far. Disregarding week 2, elimination for the greedy paths happens week 5, and in week 11 for the ENPSO paths.

The next set of paths demonstrate the outcomes if the NO Saints had won in week 2, the greedy paths change week 5 selections, and ENSPO paths change week 11 selections.
Greedy Path 1 – Contestant eliminated week 8.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
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<th>3</th>
<th>4</th>
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<tbody>
<tr>
<td>Team</td>
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<td>NYG</td>
<td>ARZ</td>
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<td>✓</td>
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<td>X</td>
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</tbody>
</table>

Greedy Path 2 – Contestant chose second highest Point Spread in week 8, and is eliminated week 12.

<table>
<thead>
<tr>
<th>Week</th>
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<td>CAR</td>
<td>CLE</td>
</tr>
<tr>
<td>Outcome</td>
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<td>✓</td>
<td>✓</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
</tr>
</tbody>
</table>

Greedy Path 3 – Contestant chose second highest Point Spread in week 12, and is eliminated week 12.

<table>
<thead>
<tr>
<th>Week</th>
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<th>2</th>
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<th>4</th>
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<th>9</th>
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<tbody>
<tr>
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<tr>
<td>Outcome</td>
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<td>✓</td>
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</tbody>
</table>

ENSPO Path 1 - Contestant eliminated week 12

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
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<th>4</th>
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</tr>
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<td>Outcome</td>
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<td>✓</td>
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</tr>
</tbody>
</table>

ENSPO Path 2 - Contestant chose alternative path 1 in week 12 and is eliminated week 12.

<table>
<thead>
<tr>
<th>Week</th>
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<tbody>
<tr>
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<td>ATL</td>
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<td>BAL</td>
<td>CIN</td>
<td>PIT</td>
<td>CAR</td>
<td>JAX</td>
</tr>
<tr>
<td>Outcome</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
</tr>
</tbody>
</table>
ENSPO Path 3 - Contestant chose alternative path 2 in week 12 and is **survives the regular season!!!**

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
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<tbody>
<tr>
<td>Team</td>
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<td>PIT</td>
<td>CAR</td>
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<td>DEN</td>
<td>KC</td>
<td>MIN</td>
<td>DET</td>
<td>IND</td>
</tr>
<tr>
<td>Outcome</td>
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<td>✓</td>
<td>✓</td>
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</tr>
</tbody>
</table>

**Conclusion**

The ultimate goal of this Project was to create a model that outperformed common heuristics of NFL Survival Pool strategies, mainly the greedy method. Based on the above findings, the ENSPO System proved superior to the greedy method.

In the 2015 season, no demonstrated paths survived past week 2. Both the first, second, and third greedy paths lost in week 2, as well as the optimal and two alternative paths of the ENSPO System. After analyzing the outcomes of this week, it was found that the top five projected favorite teams, based on the Vegas Odds, all lost during this week. Team ESPN felt that no model could have projected these extremely unanticipated performances. Disregarding week 2 in 2015, the ENSPO paths survived until week 11, where the Greedy paths only made it to week 5.

Team ESPN further investigated the 2015 season. Simulations were completed to show what would have happened if the NO Saints had won in week 2, the greedy paths changed week 5 selections, and ENSPO paths change week 11 selections. The first greedy path made it to week 5, and the two alternative paths made it to week 12. The optimal ENSPO path along with the first alternate path made it to week 12; the most impressive result was that one of the alternate paths survived the entire NFL regular season.

The conservative paths in 2015 were of no comparison to either the greedy paths or the ENSPO paths. Team ESPN concluded the ENSPO System outperformed the greedy and conservative methods in the 2015 season.

The success of the ENSPO System extends beyond the performance of the system. The ENSPO System is a fully integrated model that involved a variety of scholarly efforts which includes but is not limited to; Operations Research, Systems Engineering, Project Management, Computer Science, Statistics, and History.

Team ESPN was able to apply various aspects of the GMU SEOR graduate program during completion of this project. Furthermore, team members incorporated facets their industry experience to enhance the project. Most importantly, Team ESPN thoroughly enjoyed completion of this Project and felt that their experience of the SYST/OR 699 course could not have been better.
Sensitivity Analysis

Sensitivity analysis was not initially scoped to be a significant effort for this Project; however, given the number of attributes unique to the ENSPO System, Team ESPN felt it was necessary to explore a few of these attributes with respect to sensitivity analysis. Team ESPN investigated variations on Pool Size, Pool Strength and the Divisional Games.

Variations on Pool Size and Pool Strength

In the 2015, the ENSPO System was simulated with a Pool Size of 100 and a Pool Strength of .75. Recall the results for ENSPO Path 1 as displayed below.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team</td>
<td>NE</td>
<td>NO</td>
<td>SEA</td>
<td>GB</td>
<td>ATL</td>
<td>NYJ</td>
<td>ARI</td>
<td>BAL</td>
<td>CIN</td>
<td>PIT</td>
<td>PHI</td>
</tr>
<tr>
<td>Outcome</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
</tr>
</tbody>
</table>

The path below shows the first five weeks of the 2015 season where the ENSPO System was simulated with a Pool Size of 5, and Pool Strength of .75.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team</td>
<td>NE</td>
<td>NO</td>
<td>SEA</td>
<td>GB</td>
<td>ATL</td>
</tr>
<tr>
<td>Outcome</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

The path below shows the first five weeks of the 2015 season where the ENSPO System was simulated with a Pool Size of 10, and Pool Strength of .6.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team</td>
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<td>NO</td>
<td>SEA</td>
<td>GB</td>
<td>ATL</td>
</tr>
<tr>
<td>Outcome</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Variations on Pool Size and Pool Strength do not have a significant impact on results. Team ESPN suggests that the “tipping point” of .50, as explained in Pool Size - Implementation be increased. Increasing this value would result in Pool Size and Pool Strength having a greater impact on $w_{ij}$ for future weeks, i.e. there would be even more of an emphasis on early weeks and less on future weeks, as Pool Size and Pool Strength are decreased. To illustrate this, analysis was completed to show how $w_{ij}$ are changed based on Pool Size, Pool Strength and the “tipping point”.

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The table below shows the number (i.e. \( w_{ij} \) multiplier) which \( w_{ij} \) values are multiplied by when the current week is 1, the Pool Size is 10, the Pool Strength is .75, and the “tipping point” is .5. The \( w_{ij} \) multipliers begin to decrease in week 9.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td>( w_{ij} ) Mult.</td>
<td>1.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>.9</td>
<td>.8</td>
<td>.7</td>
<td>.6</td>
<td>.5</td>
<td>.4</td>
<td>.3</td>
<td>.2</td>
<td>.1</td>
<td></td>
</tr>
</tbody>
</table>

If the “tipping point” is adjusted to .75, \( w_{ij} \) multipliers begin the decrease in week 6, versus week 9, as displayed below.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td>( w_{ij} ) Mult.</td>
<td>1.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>.923</td>
<td>.846</td>
<td>.769</td>
<td>.692</td>
<td>.615</td>
<td>.538</td>
<td>.461</td>
<td>.384</td>
<td>.307</td>
<td>.230</td>
<td>.153</td>
<td>.076</td>
</tr>
</tbody>
</table>

As expected, changing the “tipping point” to an even higher value of .95 results in decrease of \( w_{ij} \) multipliers in week 4 as displayed below.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
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<th>3</th>
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<th>5</th>
<th>6</th>
<th>7</th>
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<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td>( w_{ij} ) Mult.</td>
<td>1.5</td>
<td>1</td>
<td>1</td>
<td>.933</td>
<td>.866</td>
<td>.8</td>
<td>.733</td>
<td>.667</td>
<td>.6</td>
<td>.533</td>
<td>.467</td>
<td>.4</td>
<td>.3</td>
<td>.267</td>
<td>.2</td>
<td>.133</td>
<td>.067</td>
</tr>
</tbody>
</table>

In addition to changing the “tipping point”, the method in which future \( w_{ij} \) values are decreased after the “tipping point” is another component of the model that could be adjusted so that Pool Size and Pool Strength have greater impacts on ENSPO results.

**Impact of Adjustments based on Divisional Games**

Another item that Team ESPN performed sensitivity analysis on was Divisional Games.

Recall the results for ENSPO Path 1, as displayed below. For this simulation, \( w_{ij} \) values were adjusted to account for Divisional Games, as explained in *Divisional Games - Implementation*.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<th>11</th>
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<tbody>
<tr>
<td>Team</td>
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<td>NO</td>
<td>SEA</td>
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<td>NYJ</td>
<td>ARI</td>
<td>BAL</td>
<td>CIN</td>
<td>PIT</td>
<td>PHI</td>
</tr>
<tr>
<td>Outcome</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
</tbody>
</table>

Team ESPN ran the ENSPO System without incorporating adjustments for Divisional Games. Weekly choices were not identical to the original ENSPO Path, and results were evidently
worse. The ENSPO path for the 2015 season without adjusting for Divisional Games resulted in elimination in Week 8 as illustrated below.

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team</td>
<td>DAL</td>
<td>NO</td>
<td>SEA</td>
<td>GB</td>
<td>NE</td>
<td>NYJ</td>
<td>ARI</td>
<td>ATL</td>
</tr>
<tr>
<td>Outcome</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
</tbody>
</table>

These results support that the inclusion of adjustments for Divisional Games impact and strengthen results of the ENSPO System.

**Recommendations to the Sponsor**

Team ESPN hopes that the sponsor will utilize the ENSPO System for the 2017 NFL season. In preparation for the 2017 NFL season, recommendations include:

- Explore fine details of the ENSPO System to determine what features would best benefit the tool supported by ESPN.
- Automate manual features of the ENSPO System. For example:
  - Automatically input each season’s schedule
  - Automatically input of recent game outcomes
  - Automatically retrieve Point Spread projections
- Simulate ENSPO System with different sources, such as Point Spreads derived from the FPI, and additional seasons and tweak the model based on these simulations.
  - Consider running similar analysis on Divisional Rivals, Team Consistency, and Uncertainty of Future Weeks on ESPN derived Point Spreads and adjust how these factors are incorporated in the solution.
- Continue sensitivity analysis began by Team ESPN on unique attributes of the ENPSO System.
- Integrate the GUI code into a web based interface.
- Continue to engage with Team ESPN for assistance/feedback!
References


APPENDIX I - Systems Engineering Documentation

Use Cases
The actors in the ENSPO System are:

- Contestant - An NFL Survival Pool Contestant
- Administrator - An administrator, such as an ESPN analyst, who adjusts internal settings of the ENPSO System.

The use cases for the ENSPO System are:

- Configure Season - An administrator configures the Optimization Model at beginning of an NFL season.
- Configure Week - An administrator configures the Optimization Model at beginning of a week of an NFL.
- Use Tool - The Contestant uses the ENSPO System to determine what team to select in order to optimize their chances of surviving the longest in the pool.

Figure 5 - Use Case Diagram

Sequence Diagrams
Each use case has an associated sequence diagram to explain the process flow between the actors of the ENSPO System and the different components of the ENSPO System.
Sequence Diagram 1 - Configure Season

![Sequence Diagram 1 - Configure Season](image)

**Figure 6 - Configure Season**

**Prerequisites** - None

**Steps** -

1. `inputSchedule` - The administrator inputs the schedule for an upcoming NFL season into the Optimization Model.
2. `domeEffect` - The administrator identifies matchups in an upcoming season where a Dome Team plays in cold weather.
Prerequisites -

1. An administrator has completed the “Configure Season” Use Case for the current season.

Steps -

1. `getPointSpreads` - The administrator obtains Points Spreads from the Projections DB for the current and future weeks.
2. `returnPointSpreads` - Points Spreads are returned to the Administrator
3. `inputPointSpreads` - The administrator inputs Point Spreads for the current and future weeks into the Optimization Model.
   a. Note: For this project, steps 1-3 are manually complete by copying data from an Excel sheet, and pasting them in the Optimization Model.
4. **initiateUncertainty** - The administrator runs a provided R function to adjust future weeks for Uncertainty.

5. **uncertainty** - Point Spreads are adjusted to account for Uncertainty in the Optimization Model

6. **conversion** - Point Spreads are converted to probabilities in the Optimization Model

7. **inputScores** - The administrator inputs scores for the previous week

8. **rivals** - Division rival data is updated in the Optimization Mode

9. **consistency** - Team Consistency data is updated in the Optimization Model

Sequence Diagram 3 - Use Tool

**Figure 8 - Use Tool**

**Prerequisites** -

1. An administrator has completed the “Configure Season” Use Case for the current season.

2. An administrator has completed the “Configure Week” Use Case for the current week.

**Steps** -
1. inputContestantInfo - A Contestant invokes the GUI by inputting Pool Size, Pool Strength, and Previously Selected Teams.

2. promptSelections - The GUI presents the contestant drop down lists to select teams previously used.

3. identifySelections - The contestant identifies all the teams they have previously selected.

4. getPaths - The GUI invokes the Optimization Model to obtain the optimal, alternative paths, and “Greedy” paths by providing the Pool Size, Pool Strength, and Previously Selected Teams.

5. adjustWeights - \( w_{ij} \) values are finalized within the Optimization Model based on the inputs from the GUI following built in adjustments for Uncertainty, Team Consistency, Divisional Rivals, and the Dome Effect.

6. optimize - The Optimization Model solves the Objective Function. The optimal path is found, along with two alternative paths and the “Greedy” path.
   a. For each of the two alternative paths, the Objective Function is solved with an additional constraint:
      i. Alternative Path 1: The team selected in the current week for the Optimal Path cannot be selected in the current week for this path.
      ii. Alternative Path 2: The team selected in the current week for the Optimal Path and Alternative Path 1 cannot be selected in the current week for this path.
   b. The “Greedy” path is computed using probabilities from the Projections DB without Uncertainty, Team Consistency, Divisional Games, the Dome Effect, and Pool Size/Pool Strength incorporated.

7. returnPaths - The Optimization Model returns the optimal path, two alternative paths, and the “Greedy” path to the GUI.

8. generateResults - The GUI ingest the paths return by the Optimization Model and generate results to display to the Contestant.

9. displayResults - The GUI displays results to the Contestant.


APPENDIX II – MODEL Administration and Usage

Downloading the ENSPO Package

The ENSPO Package, ENSPO.zip, contains a number of supporting files that are used to run the GUI and administer the ENSPO System. Many of the files are only used in the backend of the model and require no interaction with users. Note that the ENSPO GUI is in only supported on Windows Operating Systems.

After downloading the content of ENSPO.zip folder:

1. Right click on the ENSPO.zip folder and click “Extract All”
2. Determine the destination for the folder.
3. View the files in the ENSPO folder. The only files that require interaction with a user are:
   - ENSPO.exe
   - Team ESPN ENSPO Model.xlsm
   - Uncertainty Adjustments.r

User Guide

This section provides information on how a contestant would use the ENSPO GUI, and recommendations from Team ESPN regarding interpretation of the results from the ENSPO GUI. The file used to launch the GUI is ENSPO.exe.

Launching the GUI for the First Time

The first time the ENSPO GUI is launched, a user will need to follow the steps below:

1. Within the ENSPO folder, right click “ENSPO.exe” and select “Properties”.
   a. From the Compatibility tab Privilege Level section check the box “Run this program as administrator”
   b. Click the OK button to exit and save changes
2. A prompt will appear, warning that “Running this app might put your PC at risk”. Click “More info”, then “Run Anyway”
3. A prompt will appear, asking “Do you want to allow this app from an unknown publisher to make changes to your device?”
   a. Note: These warnings are displayed because the Publisher (i.e. Team ESPN) is unknown to the computer. Warnings may differ based on the Windows version of the computer.
4. If not already installed, R 3.3.1 will be initially installed automatically.
5. After R is installed, the ENSPO GUI will be launched. A “Loading...” screen will initially display. Once loading is complete, the primary GUI appears.

Once this process has been complete once, the GUI can be launched without steps 1-4.
Using the GUI

Before the first game of an upcoming week during an NFL season, an NFL Survivor Pool contestant would follow the steps outlined below to use the ENSPO GUI, displayed in Figure 9 - GUI Steps 3-5 and Figure 10 - GUI Step 6-7.

1. Launch the ENSPO GUI (depending on if/how the GUI were integrated in a live service, this could be navigation to website, or downloaded a tool connected to the central ENSPO System). For this Project, the GUI is launched via running the ENPSO.exe file as depicted above.

2. If desired, click the “Definitions” button to view information about the input parameters the click “Close” to exit the window to move on.

3. Input the “Pool Size” - this is the number of contestants currently active (i.e. not eliminated) in the pool.

4. Input the “Pool Strength” - this is the average chance a contestant in the pool will survive the next week. A contestant could base this on a number of factors. For example:
   a. If a contestant believes other contestants in their pool are very knowledgeable about NFL games and likely to choose a strong team in the next week, he/she may input a high value for “Pool Strength”.
   b. If a contestant is aware that other contestants in their pool are left with weak teams, he/she may input a low value for “Pool Strength”.
   c. If a contestant has no idea what to input for “Pool Strength” Team ESPN suggests that 0.75 be used as a default value.

5. Input a value for “Number of Previously Selected Teams” - this is the number of previously selected teams a contestant can no longer use. In most pools, this will be the number of completed weeks in the season; however in some pools, contestants may be able to reuse teams, so this value could be less than the number of completed week. Alternatively, this value could be larger than the number of completed weeks in a season if a contestant desired to completely remove a team from being included in results. Click the “Number of Previously Selected Teams” button when complete.

6. If number of previously selected teams is greater than 0, identify the teams you have previously selected and/or can no longer use or want to use.

7. Click “Submit”
8. The ENSPO GUI displays three different paths in addition to the “Greedy Path” for a contestant to analyze. Multiple paths are provided in the event a contestant prefers not to choose the team specified for the current week in the optimal path. These alternatives paths show the ENSPO system recommendations using different teams in the current week. A graphical comparison of paths is displayed after completing steps 1-7 as seen in Figure 9 - Graphical Comparison of Paths. This graphical comparison displays a line graph of the cumulative probabilities for each the optimal path, two alternative paths, and the greedy path. This provides a visual representation of how the paths compare with each other.
9. Left click inside the graph to continue.
10. The Team ESPN ENSPO Model.xlsm is displayed showing details for the different paths. Each path includes two sets of probabilities. The probabilities listed under “Team Probability” reflect the probability that the specified team will win during the associated week. The probabilities listed under “Cumulative Probability” reflect the chances of surviving through the associated week, if a contestant were to choose the teams listed for each week. Figure 10 - Example in Week 1 provides an example of a path when it is currently week 1.
Figure 10 - Example in Week 1

Figure 11 - Example in Week 14 provides an example of a path when it is currently week 14.

Figure 11 - Example in Week 14
Administrative Guide

This section provides information on administration of the ENSPO System. The files Team ESPN ENSPO.xlsm and Uncertainty Adjustments.r are the components of the Optimization Model involved in administration.

Preseason Administration

- Before an NFL Season, the Administrator is required to input the schedule for the upcoming NFL Season in the “Current Year Info” tab of the Team ESPN ESNPO Model.xlsm. Instructions are provided within the tab detailing the required actions. Figure 14 - Input Upcoming Schedule displays a screenshot of the tab and instructions.

INSTRUCTIONS FOR ADMINISTRATOR:
1. Enter the entire season schedule at the beginning of the season. *Note: This only needs to be done once!
2. Enter the scores each week in the "Home Score" and "Away Score".

![Figure 14 - Input Upcoming Schedule](image)

- Assuming the Administrator desires to incorporate the Dome Effect in the model, the administrator would need to identify games where Dome teams play in a cold weather climate in December. This is achieved in the “Matchup Identifiers” tab of the Team ESPN ESNPO Model.xlsm. Instructions are provided within the tab detailing the required actions as displayed in Figure 125 - Identify Dome Effect.
Weekly Administration

After the completion of all games in a week, the administrator is required to update the Optimization Model with closing Point Spreads and the previous week’s game outcomes. This is required to take place before the ENSPO System would be available for live use. Since weekly games take place Thursdays, Sundays, and Mondays, Team ESPN suggests:

- The tool be available for live use the Wednesday 800ET - Thursday 1400ET giving the administrator adequate time to update the Optimization Model, and use the most up to date projections for the upcoming and future weeks.

The following actions are required to take place before the ENSPO system can be used by an NFL Survival Pool Contestant each week.

- The administrator must update the “Initial Spreads” tab in the Team ESPN ENSPO Model.xlsx. An administrator may choose any source or method for deriving Point Spreads (reference the Projections Database Section for information on how Team ESPN derived Point Spreads for validation purposes). Instructions are provided within the tab detailing the required actions as displayed in Figure 136 - Input Point Spreads.
The administrator must use and execute the function in Uncertainty Adjustments.r to adjust Point Spreads for Uncertainty of Future Weeks. To run this file, the administrator must save and exit the Excel file, run the R model, and then open back up the Excel file.

- If the excel file is saved as a different name, the source file inside the R code needs to be adjusted to reflect said name change. Also, if the tab name changes from "Initial Spreads" this also needs to be reflected in the R code.

In the “Current Year Info” tab of Team ESPN ESNPO Model.xlsm the administrator is required to input scores for the most recent week. Instructions are provided within the tab detailing the required actions as displayed in Figure 14 - Input Weekly Scores.