STAT 4800 Expected Points Simulation Write-Up

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I. Introduction

A. Our question of interest is exploring the expected points for fourth down situations from a variety of yard lines (own 40-yard line to opposing 40-yard line) which we will call “no man's land” and distances (1-yard to 10 yards). We will be calculating the expected points for punting, going for it and converting, and going for it and failing. In addition, we will be calculating expected points for kicking a field goal, going for it and converting, going for it and failing; however, we will be calculating these values from the opponent’s 40-yard line inwards, which are situations where kicking a field goal is logical. Using these values, we will generate probability of success coaches should have for going for it to be more advantageous over punting or kicking a field goal.

B. This question is especially important to explore now due to the current state of the NFL. More teams are using analytics to decide whether or not to go for it on fourth down. With offense becoming more focal in the overall game plan, teams want to be more aggressive when deciding on what to call on fourth down. Calculating expected points for a variety of fourth-down situations can help coaches make more informed decisions on what course of action to take on fourth-down and can lead to better game management overall. Being able to produce a coach’s cheat sheet with field position and distance and corresponding probabilities needed for an advantage is especially important for situations where a quick decision is needed or there is no computer permission or access.

II. Methods

A. To calculate expected points for the situations described above, we modified our original simulation in a few ways. Our original simulation implemented a recursive function where we inputted yards to go, field position, down to go, and team with possession in order to simulate football plays until a score from these starting values. We adjusted this recursive function so that it returns point values for a score (field goal: +/- 3, safety: +/- 2, and touchdown: +/- 7) and then returns itself with updated parameters in all other situations (pass, run, interception,

fumble, punt, missed field goal). Additionally, we adjusted our simulation to have built-in decision-making for all subsequent fourth-down scenarios. We decided that anything 40 yards inwards would be a field goal attempt, anything between the 50-yard line and the opponent's 40-yard line that was 4th and 2 would be attempted, and any other position and down would be a punt. Once this was implemented, we ran our simulation starting from the inputted field position, down, distance, and team with possession 30 times to get 30 different points values which we take the average of. We ran this same setup 5 times to get a range of expected points values. We then used Monte Carlo simulation to simulate expected values from a normal distribution using the mean and standard deviation produced by the simulation. This gets us our final output of a range of expected point values from the different fourth-down situations. From here, we used the mean of these ranges for expected points to calculate the probability of success you need in order for going for the fourth down to be more advantageous than the other option in comparison (punt or field goal). We made an important assumption that the probabilities for the field goal make or missed multiplied by expected points for the respective value in the calculation would be filled in as values drawn from the field goal probability distribution we built for our simulation. We made this assumption so our main focus in the calculation would be the probability variable for converting and failing to convert, so we could determine how confident you had to be with the play call. Finally, we used these probabilities to fill out our coach's probability "cheat sheet."

B. It made much more sense to adapt our first function to no longer print values and return expected points, so we could easily store these values over many simulations. Our structure of leveraging recursion made this change very straightforward when we decided on our question of interest. The main modification to justify is the use of a normal distribution for a Monte Carlo simulation. We used a normal distribution because we looked at the different simulation runs and saw that each situation roughly came out to represent a normal distribution. Also, thinking about it logically, when running a large number of times, the simulation will achieve a normal distribution. The reason for

using Monte Carlo was to obtain more values without waiting hours for even more simulations.

III. Results

A. We were able to produce graphs for expected points and two csv files to assist with decision-making on 4th down. The first sheet focused on trying to convert a fourth down versus punting, and the second sheet focused on trying to convert a 4th down versus kicking a field goal. Each sheet has separate probabilities based on field position and distance that you need to have in order for the 4th down conversion to be more beneficial than the second option. Our punting sheet produced probabilities for distances from 1 to 10 for all yard lines from your own 40-yard line to your opponent's 40-yard line. Our field goal sheet produced probabilities for distances from 1 to 10 for all yard lines from the opponent's 40-yard line inwards. The probabilities represent how confident you need to be in converting a fourth down against either punting or kicking in the respective scenarios based on the expected points of converting, not converting, punting, and kicking.

IV. Discussion

A. Through simulation, we were able to generate expected points about each 4th down play call decision and probability of success needed for running a play to be most advantageous. This can help real-time decision-making for coaches to make the best possible choice.

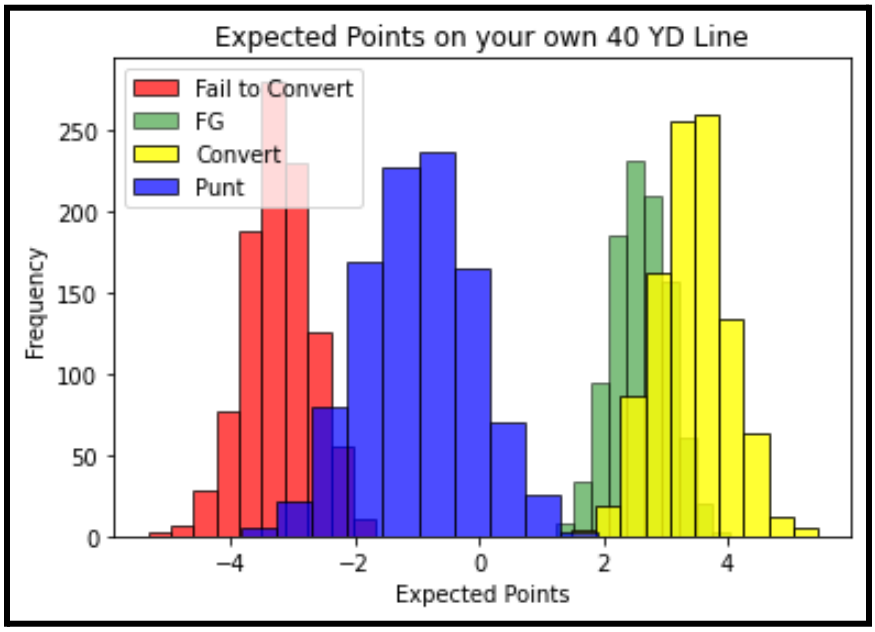
B. We found that the choice to go for it, punt, or kick a field goal all depends on field position and coach confidence. The results indicate that certain decisions, such as going for it, may be riskier and result in negative expected points. However, if a coach is feeling particularly confident about his team, then he may take the risk to cash out on a big play. Something we found interesting was that not all 4th down conversions are worth the same. It is much more valuable to convert on 4th down when you're in the opponent's territory than your own. The expected points of fourth down conversion on your own 40-yard-line are +3, while inside your opponent's 40-yard-line, it moves to +5. One thing that the graphs do not account for is the coaches' feel of the game. If a coach has historically performed poorly

on 4th down conversions, then he may feel they should punt. Statistically, this makes sense because as his probability decreases for converting a 4th down, so does the expected amount of points. So a better bet would be to punt and hope to get the ball back after a defensive stop. It was very interesting to note that for the field goal probabilities, the coach's confidence in play calling needed to increase, which we had first thought was counterintuitive because the closer you are, the more likely you are to get a touchdown over 3 points. However, when analyzing the values, we realized that in situations where the 3 points are almost a guarantee, it could be a better decision to just take the points depending on the game situation. This was a very surprising finding to us and one that we would be curious to research more in-depth to understand better. Additionally, for our punting results, we noticed the confidence for converting mostly decreases the closer you are to your opponent's goal line. This makes sense as punting does not change field position as dramatically and converting makes it much more likely to score points the closer you are to the goal line. Lastly, for both the punting and field goal sheets, we noticed that the distance does not have a great effect probability. This also makes sense as we started our simulations under the assumption that the team gained the exact yardage they needed or no yardage or punted or kicked a field goal. It would be interesting to compare our probabilities needed for success against how likely certain plays are to gain certain distances.

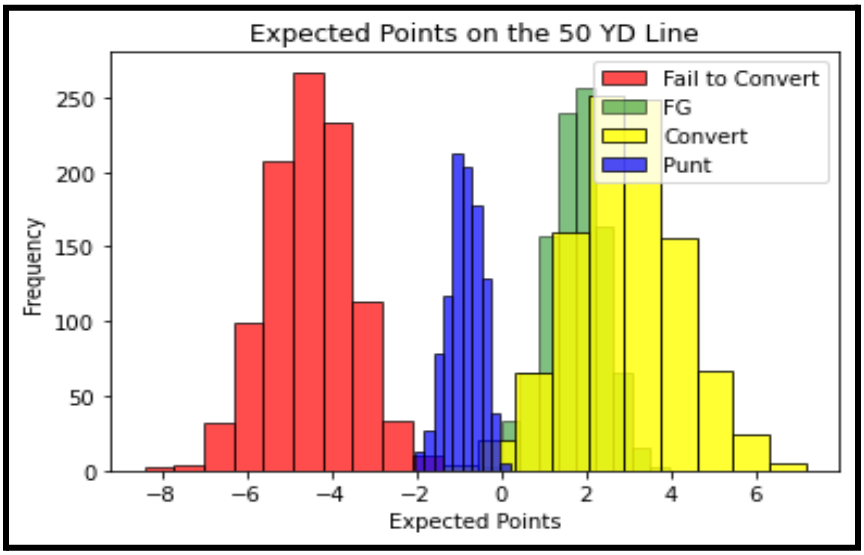
C. One limitation of our model is that a team learns more about themselves and the opposing team as the season progresses. Due to this, the probability of success for making it on the fourth down or not can vary greatly and will need to be taken into account when using our expected points model. If we had more time, we would have found a way to incorporate probability more into the model. We could have also tried looking at player personnel on different teams to see if the types of players a team has increases or decreases their probability of success on fourth down tries. Another item to consider is a team's playbook and type of playcalling. If a team is typically more aggressive and has more experience running aggressive plays, they might fancy their chances more on fourth down, which is something we could have tried to incorporate into our model.

Graphics

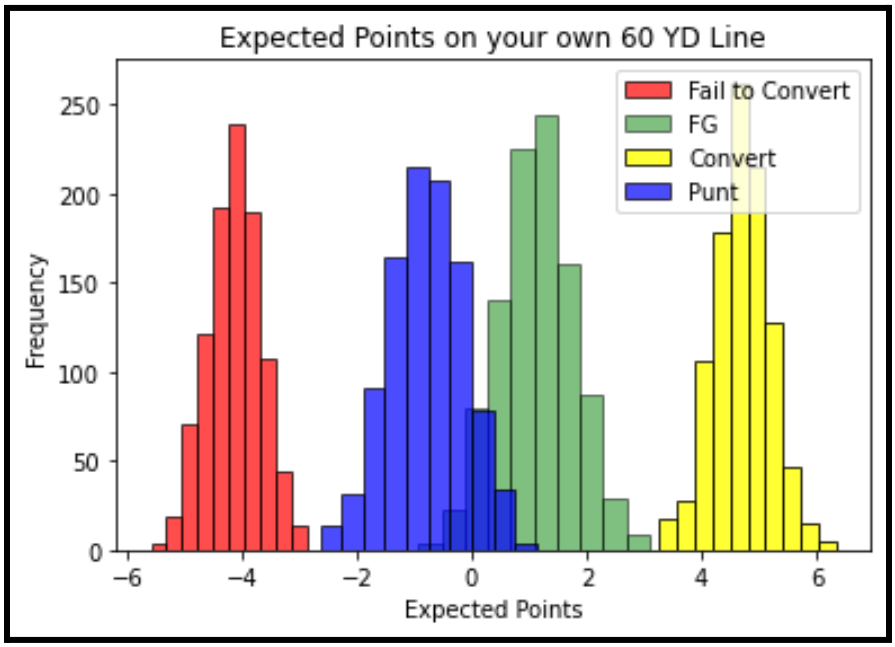
Histogram of expected points of different choices (Fail to convert, FG, Convert, or Punt)
4th and 5 on own 40 YD Line



Histogram of expected points of different choices (Fail to convert, FG, Convert, or Punt)
4th and 5 on 50 YD Line



Histogram of expected points of different choices (Fail to convert, FG, Convert, or Punt)
4th and 5 on own 60 YD Line (Opponents 40 YD Line)



"Cheat Sheet" Confidence Probabilities (Going for it vs. Punt)
4th and 1 through 10 on own 40 YD Line to opp 40 YD line

	4th and 1	4th and 2	4th and 3	4th and 4	4th and 5	4th and 6	4th and 7	4th and 8	4th and 9	4th and 10
Own 40	32.43949743	33.68941374	34.26862304	34.44043013	34.68906731	35.2184681	35.62522174	36.21358851	36.34970793	36.39300239
Own 41	36.36898387	36.51643133	36.36164344	36.67824223	36.69975645	36.54937234	36.67881041	36.60065577	36.62576306	36.63721337
Own 42	36.78404077	36.76316966	36.76721601	36.80517572	36.68608242	36.80068909	36.78062838	36.77016806	36.65659022	36.68321727
Own 43	36.6750667	36.69138824	36.71852	36.69947965	36.70601947	36.62105135	36.63656066	36.56229639	36.57296418	36.62042628
Own 44	36.69866433	36.55208333	36.59045827	36.5794755	36.6176281	36.66437557	36.64152792	36.56622951	36.62508341	36.55097176
Own 45	36.59951748	36.50722492	36.51826513	36.64334697	36.51449172	36.67793641	36.57375237	36.53231509	36.55092832	36.55974755
Own 46	36.61738285	36.48941707	36.48871793	36.47435596	36.46096697	36.38795089	36.50237823	36.40753374	36.49447753	36.3710889
Own 47	36.44650283	36.47073138	36.31898342	36.3939139	36.32182318	36.32230824	36.3344364	36.27622264	36.39237057	36.20876798
Own 48	36.26649127	36.23579479	36.29755892	36.27789358	36.09948644	36.18788805	36.17029893	36.23056949	36.10852688	36.19237531
Own 49	36.13353025	36.12366665	36.14997513	36.16345108	36.1178133	36.01904275	36.07133974	36.1132705	36.05477989	36.07689546
Own 50	35.98591028	35.95206252	36.04110588	36.00617156	35.98315172	35.91391898	35.9445359	35.98083386	35.92868661	35.90236226
Opp 49	35.89504403	35.8741224	35.79288453	35.91706195	35.82928221	35.89716846	35.8770696	35.88472567	35.74919556	35.7168632
Opp 48	35.6905195	35.71084942	35.77860215	35.68402438	35.77859264	35.78370005	35.75747919	35.75830395	35.73773139	35.64600353
Opp 47	35.68984878	35.73027615	35.61496014	35.67191898	35.64749546	35.65563663	35.50063514	35.73581821	35.62489522	35.61883105
Opp 46	35.74477774	35.6073927	35.73348829	35.55926661	35.61472319	35.63468659	35.70431282	35.46545758	35.58681339	35.56915317
Opp 45	35.52670894	35.5480728	35.59482091	35.52209418	35.38277351	35.51837862	35.54078607	35.55354561	35.49356646	35.58082568
Opp 44	35.38449241	35.48506218	35.43501253	35.59723871	35.52638146	35.49836059	35.4636327	35.42945658	35.44433928	35.4455362
Opp 43	35.46944926	35.47739499	35.42130234	35.37077532	35.58264493	35.34680977	35.25582929	35.36271647	35.45929944	35.28894168
Opp 42	35.3862174	35.30028929	35.2141085	35.41318767	35.32733089	35.25020546	35.17886154	35.2348796	35.19214474	35.21792551
Opp 41	35.22759015	35.14402012	35.25612095	35.30316012	35.05994914	35.14247932	35.24981095	35.16820214	35.18761311	35.22037815
Opp 40	35.05068949	35.17749164	35.21245053	35.10668103	35.17303214	34.97483816	35.06850629	34.97548823	34.98296214	35.12271755

“Cheat Sheet” Confidence Probabilities (Going for it vs. FG)
4th and 1 through 10 on own opponent’s 40 YD Line to 1 YD line

	4th and 1	4th and 2	4th and 3	4th and 4	4th and 5	4th and 6	4th and 7	4th and 8	4th and 9	4th and 10
Opp 40	32.0244819	33.50820493	33.21346364	33.30723138	33.28073301	33.12034101	33.14259925	33.23837969	33.16618328	33.21982773
Opp 39	34.50833732	34.57237604	34.5513736	34.54912866	34.41042871	34.43234569	34.39357524	34.34975902	34.36639789	34.30332332
Opp 38	35.68406466	35.61600397	35.66098703	35.69329486	35.59247727	35.53187942	35.5941658	35.56182085	35.49660267	35.55062548
Opp 37	36.98278631	36.92033072	36.97693193	37.06020537	36.87166952	36.90755708	36.9062799	36.84642259	36.83579554	36.80070926
Opp 36	38.22920709	38.1986893	38.1835725	38.09321202	38.05857333	38.08200321	38.11210454	38.09985086	37.93155028	38.06394229
Opp 35	39.38275932	39.2613918	39.37062244	39.31935954	39.27413114	39.34177225	39.22145374	39.22041493	39.27169518	39.26778254
Opp 34	40.62613349	40.57157405	40.64157885	40.54352356	40.4735606	40.56122556	40.56570852	40.57677034	40.53271771	40.41902528
Opp 33	41.85420156	41.7256699	41.84859545	41.77909007	41.77386067	41.65029363	41.72543094	41.5865108	41.68676605	41.64966703
Opp 32	42.93204616	42.97275579	43.0057051	43.05439327	43.02346615	43.09605748	43.01120339	43.04886078	43.03190626	42.93840154
Opp 31	44.20186261	44.1619892	44.15797692	44.09323136	44.07188423	44.10147284	44.08636965	44.11110697	44.06191207	43.9113358
Opp 30	45.30129272	45.25672332	45.19892018	45.3750255	45.20642989	45.25725307	45.23738115	45.2109421	45.16463746	45.1673119
Opp 29	46.41506365	46.36345098	46.36787359	46.31175112	46.4058755	46.21421374	46.37353231	46.19339922	46.343406	46.39565833
Opp 28	47.57082	47.40871013	47.54145158	47.28433534	47.41304465	47.42904568	47.37942309	47.33875671	47.37345565	47.39594131
Opp 27	48.47598696	48.4711799	48.56561815	48.54317085	48.52339581	48.5036543	48.51451522	48.46490201	48.39963897	48.34977332
Opp 26	49.62531099	49.46413218	49.46843769	49.31867674	49.48824327	49.35541741	49.38899876	49.51560229	49.17240297	49.44213391
Opp 25	50.37415288	50.44241725	50.48904566	50.382928	50.59479258	50.346855	50.30478832	50.3629113	50.24862202	50.16483464
Opp 24	51.38291053	51.44478594	51.28807572	51.37578373	51.27077209	51.24271161	51.21696621	51.2703888	51.3739653	51.20938885
Opp 23	52.19651725	52.09404017	52.07859083	52.07094896	52.1503084	52.19725529	52.08568012	51.89527228	52.14521963	52.13017097
Opp 22	52.98576771	53.03315374	53.0780176	53.13130759	53.00803282	52.88714947	52.9542853	53.0430911	52.92875933	52.94500144
Opp 21	53.96139483	53.86287161	53.78002664	53.69576497	53.9704149	53.71120832	53.69367662	53.75397547	53.7292742	53.59904702
Opp 20	54.44540589	54.40373028	54.51186503	54.50256218	54.3780449	54.46443077	54.40181124	54.54634918	54.50916889	54.31311488
Opp 19	55.35090983	55.38433295	55.1658099	55.16230521	55.36395606	55.00754662	55.10458102	55.20500399	55.02707687	55.04728821
Opp 18	55.68843874	56.07104135	55.72524083	55.67996925	55.8224394	55.76063343	55.7966848	55.7713084	55.60456946	55.55566063
Opp 17	56.47377136	56.33943015	56.45301785	56.4644811	56.24743723	56.23661097	56.40124121	56.17101737	56.1695726	56.19605547
Opp 16	56.90768022	56.9652926	57.09648416	56.99236764	56.81385556	56.82304979	57.06678352	56.70303821	56.88807506	56.69255751
Opp 15	57.49669166	57.39127888	57.41847477	57.60569191	57.23846156	57.30042932	57.35610263	57.18534331	57.21896671	57.49453798
Opp 14	58.01901081	57.75113915	57.88281973	57.90855956	57.97736587	57.77323262	58.22234719	57.97837223	57.99642407	57.79794551
Opp 13	58.47816602	58.42421362	58.31665892	58.2169306	58.51708788	58.16034026	57.97230902	58.23769508	58.02231435	58.15642145
Opp 12	58.82917796	59.10957851	58.78283271	58.60660768	58.52024109	58.79662001	58.43328731	58.76684304	58.51421477	58.5558675
Opp 11	58.87122068	58.93994409	58.98872208	59.00668717	59.25054673	58.89979002	59.10335626	59.0275769	58.83607407	59.0152071
Opp 10	59.6074252	59.60899662	59.53245624	59.44618977	59.37953971	59.17899516	59.4280523	59.37506936	59.11376518	59.17830421
Opp 9	59.63378346	59.60114416	59.58085726	59.6253154	59.30009289	59.61175883	59.7001723	59.57064598	59.74395105	59.75563441
Opp 8	60.10713545	59.79651314	60.08640589	60.02853847	59.82672759	59.62107886	59.80270721	60.10879356	59.6793412	59.8064791
Opp 7	60.29373844	59.83027853	59.98287886	59.92169816	60.07729229	60.47702897	60.20484707	60.2962049	60.06748298	60.02933966
Opp 6	60.20607276	60.27947266	60.19054659	60.45895873	60.29853872	60.29969112	60.38155446	60.00399893	60.08863458	59.93125984
Opp 5	60.27030375	60.66817927	60.37218605	60.67802624	60.23478434	60.3092968	60.36444602	60.25122123	60.31454533	60.2507856
Opp 4	61.05382947	60.54650662	60.74749306	60.7750224	60.40729134	60.31862926	60.79276503	60.35549351	60.1174774	60.26350307
Opp 3	60.65212076	60.74250946	60.47746754	60.80312852	60.50170782	60.66153521	60.89377919	60.18506811	60.51995376	60.57280845
Opp 2	61.03395094	61.04945455	60.76666077	60.74758472	60.79079126	60.92624998	60.77351931	61.15202626	60.72519583	61.03926822
Opp 1	60.89133038	60.94864251	60.95140438	60.83642714	61.09385333	61.04275971	60.96142721	60.72388516	60.58924869	60.51070585