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A Dynamic, Scalable Algorithm to Optimize the Allocation of Athletics Scholarships

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Abstract

When a high school student athlete makes the decision to swim collegiately, one of the leading factors in choosing a university is the amount of the scholarship award. These awards are determined by the equivalency category in the National Collegiate Athletic Association (NCAA) Divisions I and II and the National Association of Intercollegiate Athletics (NAIA). Rules govern financial aid and the number of scholarships allowed by a member institution. The exact financial distribution among athletes, however, is mostly the coaches' responsibility and there is scarcity in the literature on how these scholarships are distributed among athletes in a college/ university, which is why it's important for Athletics Departments within these colleges and universities to have a model to help distribute the scholarship amounts in an optimal manner that promotes transparency and ethical leadership. This paper provides a model to aid coaches in the distribution of financial award/ scholarships in a women's swimming in a major urban university; however, the model can be applied and adjusted for financial award distribution for any collegiate sport following any institute specific policies and preferences.

Key words: scholarship allocation, women's swimming, collegiate sports, award assignment, modeling

1. Background

The aim of this research is not only to develop an algorithm to optimize the allocation of scholarships for women's swimming for a particular university or college, but also one that can be scaled to handle the optimization of this process for any sport at any university regardless of the school's budget.

Having a tool that is consistently used to portray specific scenarios for scholarship allocation can reduce bias and help promote ethical leadership which has been a major area of concern in the past decade (Burton & Peachey, 2014; Roby, 2014; Lumpkin &Doty, 2014; Nite & Bopp, 2017). Tools, algorithms, and models have been created to identify the factors that would contribute the most to the likelihood of receiving scholarships during the recruitment process, but there is a shortage in research on how scholarship amounts are distributed once athletes are hired (Pitts & Rezek, 2012). This distribution is currently done by team coaches and how valuable they perceive an athlete would be to the team (Bock, 2016). This raises a lot of concerns and introduces personal bias, since coaches can also change and cancel scholarships at any time (Bock, 2016). There is already so much debate on whether student athletes are getting enough and whether this entire program is successful and fair (Bock, 2016; Rosenblum, 2021). With the limited scholarships available for distribution, following a standard model would at least reduce bias in part of the process (Wolverton, 2016).

There are three main organizations that govern college athletics: National Collegiate Athletic Association (NCAA) ("National Collegiate Athletic Association,"), National Association of Intercollegiate Athletics (NAIA) ("National Association of Intercollegiate Athletics,") and, National Junior College Athletic Association (NJCAA) ("National Junior College Athletic Association,"). According to the NCAA, there are nearly 8 million students currently participating in high school athletics in the United States, but only 495,000 (~6.2%) of them will compete at NCAA schools, and only 180,000 (~2.3%) will actually receive any type of scholarship averaging about $20,000 each (a total of almost $3.6 billion). Additionally, the NAIA offers about $800 million in scholarships to about 77,000 athletes (Tinodi, 2018).

Table 1. Breakdown of scholarships across all Divisions

Division	Teams	Scholarship athletes	Team-size average	Scholarships Limit / Team
NCAA D1	200	5,500	28	14
NCAA D2	77	2,000	19	8.1
NCAA D3	242	5,100	20	--
NAIA	31	350	11	8
NJCAA	21	150	12	15
CCCAA	56	745	14	--

As shown in Table 1, a breakdown of women's swimming by Division, detailing the number of athletes and number of scholarships awarded in North America is presented.

Coaches divide scholarship awards in different manners (from a full scholarship, paying partial tuition, room and board, to the price of books). They are able to construct multiple combinations for any number of swimmers and divers, as long as the total doesn't exceed the equivalent of the allowed full scholarships, based on the budget given to the sport.

The coaches make the difficult decisions of how to distribute scholarships amongst the roster; some try to distribute them equally in order to sign as many good players as possible, while others try to recruit a few super stars with "full ride scholarships" and distribute the remaining among the rest. While equivalency sport scholarships allow for flexibility, coaches are generally not satisfied with the equivalency sport scholarship allocation algorithm and have to spend much time and effort making it work.

This is where creating an algorithm for the process of award assignment that takes into consideration the necessary constraints is both important and useful. It is important because it helps decision-makers optimize the process of awarding the available scholarships for all stakeholders. It is also useful since it allows a coach to use scenarios to allocate scholarships in a scalable, relevant algorithm in a faster and simpler way. In addition, the algorithm and scenarios in this paper can be used to optimize scholarship awards for other sports regardless of the school's budget, periodic graduations, terminations, hires, and/or any other constraints.

The algorithm will present three different scenarios and can handle periodic graduations, terminations, and hires. In addition, the algorithm accurately reflects periodic constraints and allows for adding and removing members to the roster and redistributing available funds. Through the results obtained, we show significant improvement to the current system being employed.

2. Literature Review

Student athletes balance difficult practice schedules while working towards a college degree. Scholarships provide vital financial support and serve as an important motivational tool to maintain that balance through competition and academic success. Milton *et al.* and Medic *et al.* discussed the impact of athletic scholarships on the academic success of the student athletes (Medic et al., 2003; Milton et al. , 2012). Sport scholarships have had a major impact on higher education not only in the US but also in Europe and other developed countries around the world; Bourke outlined the origin and evolution of sport scholarships programs in the US, their introduction into Ireland in the late 1990s, as well as their impact and changes in European Union education policies pertaining to student athletes (Bourke, 2020).

According to the NCAA, more than $3.6 billion are awarded every year in athletic scholarships to more than 180,000 students (Medic et al., 2003). To help parents whose children intend to swim at a collegiate level, Lombana from collegeswimmingguide.com breaks down the different divisions of the three organizations mentioned above and what they offer in terms of scholarships and financial aid to colleges to distribute among their rosters (Lombana, 2020). In addition, Shekhtman in sportsrecruit.com discusses the good, the bad, and the ugly faces of athletic scholarships and the difference between headcount scholarships and equivalency scholarships (Shekhtman, 2017). Leccesi, on the other hand, a former college athlete, coach and NAIA national champion and is part of the Next College Student Athlete, developed a network meant to help parents and students become better recruits (Leccesi, 2017). There are many resources available to recruits and their parents to help them navigate the process of financial aid, and much work is being done to address lesser well-known tips and secrets about athletic scholarships (Drotar, 2021).

There are few misconceptions about athletic scholarships, and some of the literature attempts to dispel them. Different sports offer scholarships in different ways: for example, level-based gold, silver, and bronze awards, where each level is awarded a specific amount, or full-ride scholarships only for headcount sports. Soriano and Kerr shed light on the five biggest misconceptions about the different sports and their scholarship distributions (Soriano & Kerr, 2021). There is much debate and controversy regarding collegiate athletics and the structure of athletic scholarships. These tackle many aspects, such as the organizational culture in athletic departments (Schroeder, 2010) or the barriers preventing the proper reform of intercollegiate athletics and the impact of its cultural significance in higher education (Beyer & Hannah, 2000). Even though leaders within the NCAA have acknowledged the need for culture change, there is still much work to be done. Debates also extend to the status of athletes, for example, as 'employees', as discussed in Rensing vs Indiana University. Porto addresses these decisions and their limitations by discussing the judicial involvement as well as the employment-like conditions under which the scholarship athlete lives (Porto, 1985).

In his analysis of the coaches' perspectives, Teich explored the perceptions of NCAA Division I coaches of the current scholarship model in regard to scholarship limits, headcount, and equivalency sports, and modifications to the distribution of scholarship dollars. Coaches are expected to distribute the scholarship funds among their teams based on their perception of an athlete's performance. Teich sampled 349 head and assistant coaches from Division I Power-5 conferences who shared their insights for this purpose. The key findings indicate that coaches across the spectrum are not very satisfied with the overall available scholarship models. (Teich, 2016) According to Teich, while equivalency sport scholarships allow for flexibility, coaches are generally not satisfied with the equivalency sport scholarship allocation model and have to spend much time and effort making it work.

Although awarding scholarships has been a standard practice for a long time, and the literature above provides some research context, standardizing compensation structure in intercollegiate athletics is a subject of debate (Weight et al., 2015), thus, having a customizable model that accounts for variability in different institutions could still have benefits.

This research bridges that gap by highlighting common strategies and presenting an algorithm that decision-makers can use with scenarios before making decisions (for example, what if you have more scholarships? What if you wanted to give the scholarships to more athletes on the team? What if you want to recruit more athletes?) to save time and effort with a customizable algorithm.

3. Methods

Taking into consideration all the limitations of the collegiate governing bodies, the universities and colleges, and the allocated budgets, we developed mathematical equations for three different scenarios that allowed us to benchmark and compare current practices with our proposed algorithm.

In all scenarios, and to make sure that the results are realistic and feasible, the athlete's scholarship award is capped at a maximum percentage (α) of tuition (σ).

Below is a list of the rest of the variables with their symbols:

Variable	Symbol
Athlete's points scored at a certain event	$\rho_{x,\varepsilon}$
Athlete's total points for the current year	ρ_x
Number of scholarships available	N_S
Tuition	σ
Maximum scholarship as a percentage of tuition	α
Minimum points to be eligible for a scholarship	ρ_0
Athlete's scholarship previously awarded (whether using the algorithm, already promised, or otherwise, depending on the scenario chosen)	$\lambda_{x,0}$
Athlete's calculated scholarship for the current year	$\lambda_{x,t}$
Current year	t
Set of athlete students	X

3.1 Scenario One

Scenario one is purely performance-based, where the current year's awards depend on the current year's performance calculated using the following formula:

$$\forall\, x \in \mathrm{X} : \rho_x \geq \rho_0, \lambda_t = \frac{\alpha \cdot \sigma \cdot N_S}{\sum_x \sum_\varepsilon \rho_{x,\varepsilon}} \cdot \rho_x \tag{1}$$

3.2 Scenario Two

Scenario two deals with maintaining the promised scholarship to the athlete when they are first being recruited, or maintaining the first scholarship being awarded, while the rest of the funds are distributed based on performance. An athlete's first scholarship amount calculated by the algorithm is carried forward regardless of current year's performance (Part A) or actual scholarship awards that were already promised before using the algorithm are also carried forward regardless of current year's performance (Part B):

$$\forall\, x \in \mathrm{X} : \rho_x \geq \rho_0, \lambda_{x,t} = \begin{cases} \lambda_{x,0}, \lambda_{x,0} > 0 \\ \frac{(\alpha \cdot \sigma \cdot N_S) - \sum_x \lambda_{x,0}}{\sum_x \sum_\varepsilon \rho_{x,\varepsilon}} \cdot \rho_x, \lambda_{x,0} = 0 \end{cases} \tag{2}$$

3.3 Scenario Three

Scenario three addresses the ranged performance-based, meaning that if a number of athletes' performances are within a certain range, the same scholarship is awarded to these athletes (while also keeping the promised scholarship constant). After carrying forward the amounts awarded before, all awards within a certain interval (θ) are averaged together and all respective athletes are awarded the average. Changing the averaging interval results in different scholarship distribution patterns.

We simulated the results obtained from the three scenarios where the calculations were performed in what is called "row context". This means that the equation is calculated in an iterative manner, i.e., the calculation happens once (an iteration) for every athlete before moving to the next athlete. In every iteration, awards of athletes in previous iterations, as well as their points, must be subtracted to avoid double counting and ensure correct proportional distribution of the scholarship funds. In other words, with every iteration, the scholarship funds available (the numerator) and the points by which those funds are divided (the denominator) both shrink.

The algorithm has been implemented in Excel as a decision support tool with a dashboard that depicts all scenarios and dynamically updates results based on the inputs. Policy changes or roster changes can be made in the inputs section of the tool. There is an option to toggle between years and universities or colleges for benchmarking or analysis purposes. This also allows the algorithm to be dynamic and not limited to one specific sport, university or college, or the number of scholarships awarded.

To leverage the algorithm, the Women's Swimming team athletic coach, for example, follows the flow chart below in Figure 1 to determine the appropriate distribution of funds according to the scenario that best reflects their strategy. After recording the results and calculating the athlete's total points and based on whether the athlete has a previous award, the coach will maneuver through the appropriate scenario to make the optimal decision.

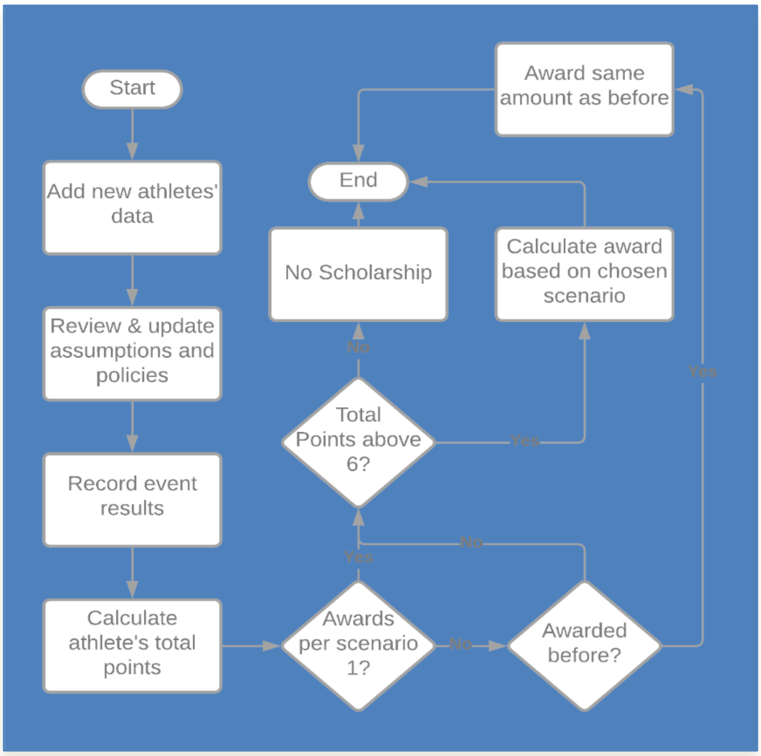

Figure 1. Scholarship awarding process for the Women's Swimming team using the algorithm

4. Results

We used the data obtained from the women's swimming team at College X to run all the scenarios with a significant number of iterations and compared them to the actual awards from the current process, and the results obtained showed significant improvement between the current process and the new algorithm for most iterations.

The flexibility of the algorithm empowers the coach and the Athletics Departments to compare and contrast to see which scenario is the best one that suits their particular sport, budget, and institution while staying within all the rules, regulations, and limitations of the award process. Results are shown in the figures 2-6, with a red line showing the actual average awarded by College X and a yellow one showing the average school scholarship award published in the literature. In the examples used, the award is capped at a random chosen tuition (the capped amount is: $54k).

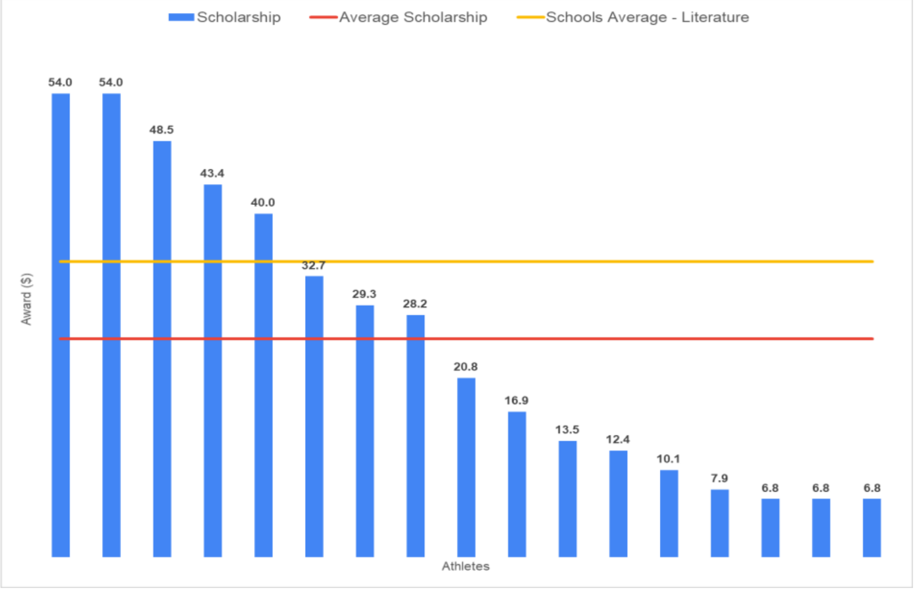

Figure 2. Scenario One: capped award for a roster of 17 students

Athletes' names were removed from the x-axis for privacy constraints. Y-axis is the award allocation in ($1000).

The results of Scenario Two are shown in Figure 3and Figure 4, where any promised scholarship is maintained regardless of the current year's performance.

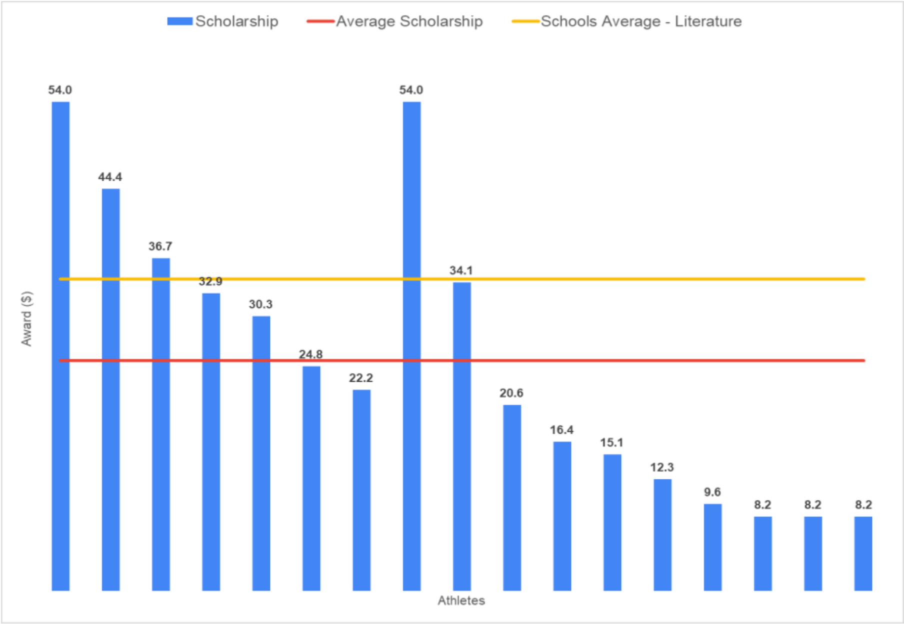

Figure 3. Scenario Two (a): promised scholarship is maintained regardless of performance

Athletes' names were removed from the x-axis for privacy constraints. Y-axis is the award allocation in ($1000).

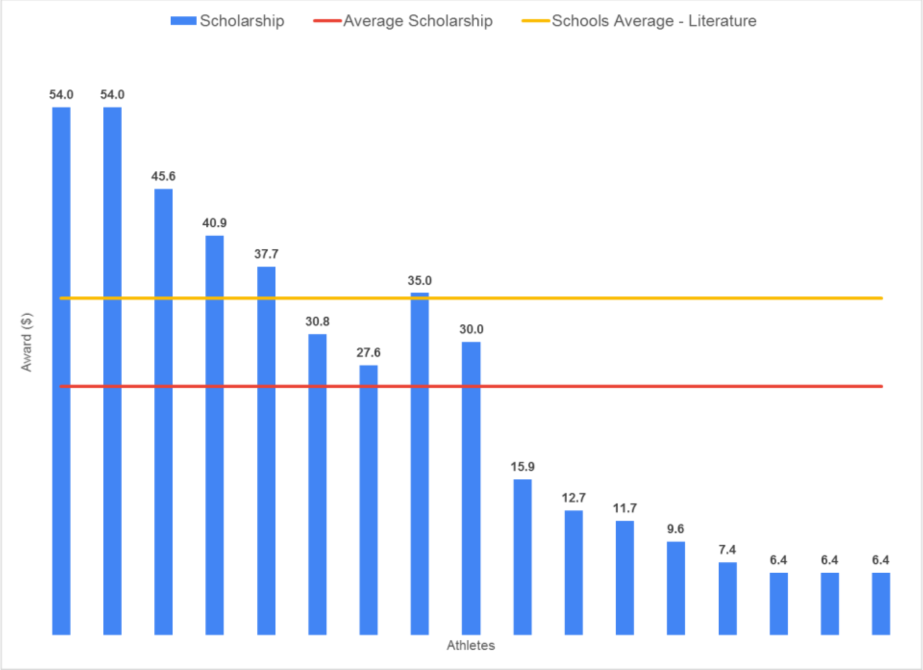

Figure 4. Scenario Two (b): starting scholarship is maintained regardless of performance

Athletes' names were removed from the x-axis for privacy constraints. Y-axis is the award allocation in ($1000).

The results of Scenario Three are shown in 5 and 6. All awards within a certain interval are averaged together and all respective athletes are awarded the average. Changing the averaging interval (θ) results in different scholarship distribution patterns. Unlike a small θ (Figure 6), a high one (Figure 5) yields a more stepped distribution.

Figure 5. Scenario Three: awards within an interval are averaged so that closely performing athletes get the same award where θ = 20,000

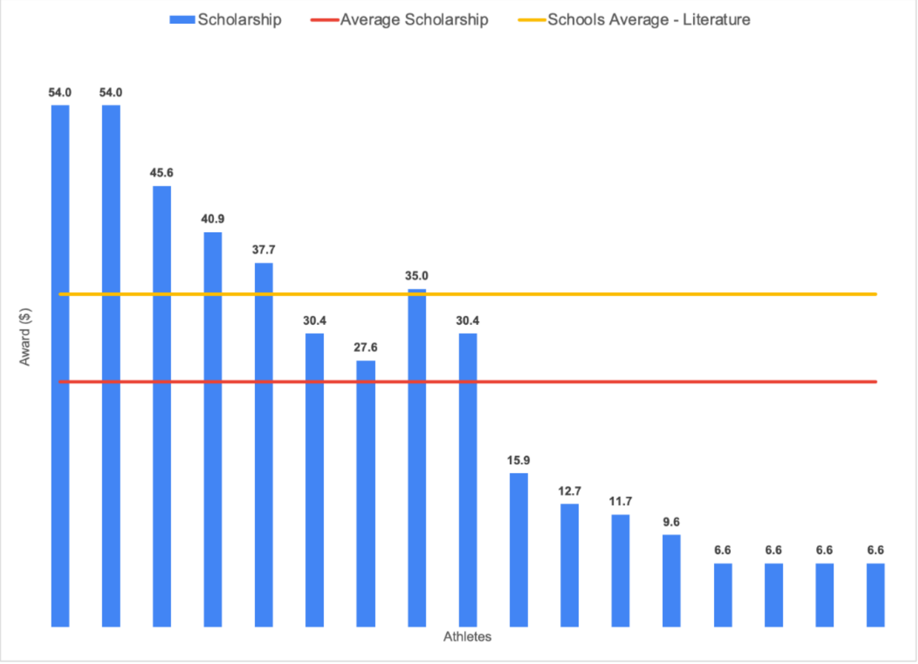

Figure 6. Scenario Three with a small θ = 2,000

Athletes' names were removed from the x-axis for privacy constraints. Y-axis is the award allocation in ($1000).

Table 2. Deviation of actual awards from algorithm recommendations for year 2021 and 2022

Measure	2021	2022
Total positive deviation	$42,324	$6,057
Total negative deviation	-$36,973	-$43,388
Total Absolute Deviation	$320,926	$199,330

Table 2 shows a summary comparison between the awarded scholarships for the years 2021 and 2022 at College X to the results from our algorithm using the scenario-based performance while maintaining promised scholarships (Scenario 1).

Table 3. User dashboard showing award result

		Scenarios			
Points	Uncapped	1	2A	2B	3 - Capped award
74.5	$ 77,739	$ 54,000	$ 54,000	$ 54,000	$ 48,628
52	$ 54,261	$ 54,000	$ 44,410	$ 54,000	$ 48,628
43	$ 44,870	$ 48,459	$ 36,724	$ 45,643	$ 48,628
38.5	$ 40,174	$ 43,388	$ 32,880	$ 40,867	$ 48,628
35.5	$ 37,043	$ 40,007	$ 30,318	$ 37,682	$ 32,213
29	$ 30,261	$ 32,682	$ 24,767	$ 30,783	$ 32,213
26	$ 27,130	$ 29,301	$ 22,205	$ 27,598	$ 32,213
25	$ 26,087	$ 28,174	$ 54,000	$ 35,000	$ 32,213
18.5	$ 19,304	$ 20,849	$ 34,054	$ 30,000	$ 32,213
15	$ 15,652	$ 16,904	$ 20,550	$ 15,922	$ 9,553
12	$ 12,522	$ 13,523	$ 16,440	$ 12,738	$ 9,553
11	$ 11,478	$ 12,397	$ 15,070	$ 11,676	$ 9,553
9	$ 9,391	$ 10,143	$ 12,330	$ 9,553	$ 9,553
7	$ 7,304	$ 7,889	$ 9,590	$ 7,430	$ 9,553
6	$ 6,261	$ 6,762	$ 8,220	$ 6,369	$ 9,553
6	$ 6,261	$ 6,762	$ 8,220	$ 6,369	$ 9,553
6	$ 6,261	$ 6,762	$ 8,220	$ 6,369	$ 9,553
414	$ 432,000	$ 432,000	$ 432,000	$ 432,000	$ 432,000

Table 3 shows the result dashboard of a hypothetical simulation where the coach selects a year and sees a list of all student athletes on the roster for that year with all scenarios for their scholarship awards. The table shows a given scenario of the number of athletes that have accumulated the points below, generating results based on two random criteria: number of athletes and number of points. With this, the algorithm allocates the scholarship amount.

The most significant aspect of our work is allowing the people in charge to use accurate analytics to optimize their process, without needing to rely on trial-and-error and/or historical practices and less-than-ideal results.

5. Conclusion and Further Discussion

Challenges exist due to the limited number of scholarships available to student athletes committed to playing sports in higher education institutions. These challenges have an impact the student's decision to pursue sports in university/college, and if so, which one to apply to. This impact extends to the university or college, their Athletic Departments, and the coaches of the individual sports who have to decide on how to distribute these limited awards, so the institution can compete at the highest level while working within the rules and limitations dictated by the governing bodies in charge of athletics scholarships.

This research provides a model to standardize the process of distributing the available scholarships based on preferred scenarios. A coach may find it faster and simpler to use such models to allocate scholarships in a scalable, relevant algorithm that removes any personal bias. Even though our research focused on optimizing the allocation of scholarships for women swimming for a particular university, the algorithm and scenarios in this paper can be used to optimize scholarship awards for any sport at any higher-level institution regardless of the school's budget.

With the algorithm's three scenarios, it can handle periodic graduations, terminations, and hires. In addition, the algorithm accurately reflects periodic constraints and allows for adding and removing members to the roster and redistributing available funds. Through the results obtained, were able to show significant improvement to the current system.

These algorithms provide a fair performance-based distribution of awards and gives a strategic view of the effect of potential hires on financials over time. The algorithms also give insight on the impact of promised scholarships in the long run after actual performance of an athlete is recorded over time. Insight on whether over-awarding or under-awarding trends can be seen. The algorithms will also save time for decision makers. Initially the coaches (decision-makers) can start looking at how much the scenarios differ from their current strategy and use the scenarios to improve that process. Thus, aiding decision makers to insure fairness and equity among student athletes.

The model can easily be adjusted to add educational performance measures, well-being, or other factors that could serve as a comprehensive tool to aid in ethical intercollegiate athletic leadership. College athletes are often admitted with lower educational standards than non-athletic students (Shulman & Bowen, 2002), but adding an educational performance measure to compare athletic students is important. In addition to scholarship allocation, such tools may aid in policy revision/adjustment.

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