Team Control Number

11318

Problem Chosen

B

2020
HiMCM
Summary Sheet

This paper focuses on devising an algorithm to create an optimal funding schedule so that the FRPCE is able to acquire the "long term and reliable" funding necessary to complete all 48 conservation projects within a reasonable timeframe. First, we identify the objectives that the FRPCE should consider when making budget decisions. We also identify the characteristics of imperiled species that should be considered by the board in determining the schedule.

With this information, we split our plan into two sections. The first section is 5 years long and consists of an initial portfolio with short projects that are highly beneficial to the environment and are very likely to succeed. By having a strong initial portfolio of projects, the board is able to signal to potential donors, grantors, or investors that there is a strong sense of direction and organization when completing these conservation projects. Investors then would be more inclined to provide "long term and reliable" funding to complete the remaining projects. In our initial portfolio, we also include the two projects that have a taxonomic uniqueness value of 1.00, as those are the projects that are most at risk for extinction. Using a Python script, we calculate all possible configurations of the initial portfolio and then choose the configuration that has the lowest standard deviation of 5-year costs, effectively allowing the board to raise funds consistently.

Our second section is 24 years long and consists of the remaining 38 conservation projects. Our plan ensures the board will receive adequate funding every year by minimizing the chance that the majority of projects fail in one year, as investors would be less inclined to fund our projects if there was a year where multiple projects failed. We minimize this chance by maximizing the feasibility one project will succeed every year by pairing high feasibility projects with low feasibility projects. By doing so, we achieve a consistent average that maximizes our success. We advise that the board does not end more than one pair of projects in the same year to maximize the positive yield of our projects and to avoid congregating costs into a short period of time.

With the pairs set in place, we utilize a greedy algorithm to prioritize the pairs that have the highest expected benefit. Using a Python script, we organized the 19 pairs of projects into a span of 25 years, finalizing our schedule for the 48 conservation projects. We then introduce a fundraising strategy that involves investing some amount of the fundraised money into an endowment to reduce the total amount of money that needs to be raised through traditional fundraising.

Overall, our solution will allow the board to achieve "long term and reliable" funding by accounting for investors' intentions and investing efficiently.

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Dear Members of the Board,

After a thorough review of the project data provided, we recommend that the board implement a schedule of the conservation projects based on our two-part algorithm. This plan will allow the board to acquire "long term and reliable" funding for all 48 projects within a 30-year timeframe.

The first part of our plan is titled "Initial Portfolio", and focuses on 10 projects that are highly urgent and/or beneficial to Florida's biodiversity. This ensures that species that are at high risk of extinction will receive immediate funding. This also builds the confidence of potential investors, donors, and grantors in the board's conservation efforts. By having a strong initial portfolio of projects, the board is able to signal to potential investors that there is a strong sense of direction and organization when completing these conservation projects. This can provide an initial boost in the fundraising needed to finance the conservation projects. Finally, these initial projects are both short and low cost, which will make the initial fundraising relatively easy.

The second part of our plan is titled "Continuous Efforts Plan", and focuses on scheduling the remaining 38 conservation projects in a way where the board can continue to receive "long term and reliable" funding. With our schedule, we ensure that for every year, there is at least one successful project. A year with multiple failures or no projects at all could signal incompetency and complacency to investors, and in such a situation, the board would be unable to secure the necessary funds required to complete all projects. We maximize the possibility of success for each year by implementing our "pairing method", where we pair projects that are more likely to succeed with projects that are less likely to succeed. Along with maximizing success for each year, we also recommend that the board implement the projects which are expected to have the most benefit first.

Taking all of this information into account, we advise that the board implement the following schedule to begin each project (in the form Year: ID number(s)): Year 1: 537, 179, 514, 530; Year 2: 502; Year 3: 536, 133, 455, 481, 548; Year 6: 137, 183, 452, 492, 560, 551, 173, 122, 415, 186; Year 7: 135, 553, 517, 127; Year 8: 476, 486; Year 9: 168, 507; Year 10: 480, 528; Year 11: 475, 546, 519; Year 12: 567; Year 14: 442; Year 15: 436, 426; Year 16: 440; Year 17: 558; Year 18: 508; Year 19: 176, 524; Year 20: 557, Year 21: 485, 543; Year 22: 529, 513; Year 25: 520. We also are able to provide the board a concrete fundraising schedule given that the board implements our solution.

Lastly, we provide an investing strategy to decrease the amount of funding needed to be acquired through traditional fundraising. We recommend that the fundraising goal for each year of our schedule be 10% greater than the costs of the projects being financed that year. That extra 10% can be put into an endowment with an interest rate. After year 19, the amount of money we have in our endowment is enough to finance the rest of the conservation projects, and we can eliminate the need to rely on traditional fundraising. This approach reduces the amount of money needed to be raised through traditional fundraising by $4,557,475.58.

Because the majority of our model is code-based, the board is easily able to adjust parameters as they see fit. The adoption of these recommendations will undoubtedly provide the board with a reliable schedule that will ensure all projects are able to be completed in a timely manner.

Thank you,
HiMCM Team #11318

Problem Statement

Florida is home to a large diversity of native plants. However, the number of imperiled species in the state has increased over time, making the conservation of these plant species a priority. The Florida Rare Plant Conservation Endowment (FRPCE) is an endowment established to fund conservation efforts for these rare and imperiled plant species in Florida. Endowments operate by generating a large principal amount of money, generally from donations, that is then invested in the market. The investment revenue is used as readily available funding, whereas the principal amount is largely left intact [1]. Conservation groups like the FRPCE must make difficult decisions in deciding how to manage their funds, as there are many imperiled species but only a limited amount of funding available for recovery projects. Their difficulties are compounded by the fact that projects require varying amounts of funding over differing timelines, and species have inherently different characteristics that must be considered. They also must plan ahead to balance long term and short term goals and funding. This paper focuses on devising an algorithm to create an optimal funding schedule so that the FRPCE is able to acquire the "long term and reliable" funding necessary to complete all 48 conservation projects within a reasonable timeframe. First, we aim to identify objectives that the FRPCE should consider when making budget decisions. We also identify the characteristics of imperiled species that should be considered by the board. Given these objectives and characteristics, we define a model to recommend a priority order and project funding timeline that best meets the goals of the organization.

Definitions

Benefit (b): The relative conservation value. A project with more benefit has higher priority since it has more "value" compared to other projects.

Taxonomic Uniqueness (u): A measure of the uniqueness of the species.

Feasibility of Success (f): The probability that the species will be protected from extinction if all of the actions receive funding.

Length of Project (l): The last year a project requires funding.

Expected Value of a Project (e): $e = f * b$
Given the definitions of feasibility and benefit, if we simulated completing a project many times, the average benefit yielded would be approximately the feasibility of the project times the benefit.

FRPCE: Acronym for Florida Rare Plant Conservation Endowment. Throughout the paper, we refer to "the board" as the FRPCE and vice versa.

Assumptions

Assumption 1: The benefit and taxonomic uniqueness of the 48 recovery projects do not change over time.

Reasoning: Plants do not change their biological characteristics over the short amount of time we are implementing our conservation projects, and the composition of plants within a project should remain static.

Assumption 2: No plant will become extinct before we are able to implement our conservation efforts within a reasonable timeframe of 30 to 40 years.

Reasoning: The projects listed in our spreadsheet are designed to feasibly conserve each plant species within a realistic timeframe. Thus, we can infer that if a plant is in a conservation project, it is able to survive until the implementation of that project, and within a reasonable timeframe (30-40 years).

Assumption 3: The feasibility of success of each project remains constant over time.

Reasoning: Projects can arguably become less feasible over time, as their endangerment could become more dire, or more feasible over time, as technology and environmental awareness should gradually improve. Therefore, it is safest to assume that the value for the feasibility of the projects, as included in the spreadsheet, takes into consideration these changes over time.

Assumption 4: A recovery project is finished after the last year that it requires funding.

Reasoning: As defined by "Feasibility of Success", as long as all of the actions needed to complete the conservation effort receive funding, then that species will be protected from extinction.

Assumption 5: If a recovery project fails to protect a species, the project is discarded from the list of projects to complete. We cannot reimplement or redo the project.

Reasoning: It would take an extraordinarily long time to reimplement every project until each one is successful. Additionally, if a project fails, a new project using the same plants would most likely take different approaches, which will change the feasibility and the cost of the project.

Assumption 6: A project yields its results once it is finished, and no time before.

Reasoning: Ongoing projects do not show results to investors until the project has been completed, as there is no way to tell if the project will definitely yield results until all actions have been funded and completed. Once a project is completed, the plant is either immediately protected from extinction or immediately not protected, according to our definition of "Feasibility of Success".

Assumption 7: A successful year is defined as a year where the majority of projects do not fail (50% or more of the projects that year are successful). Successful years lead to increased investment; unsuccessful years lead to decreased investment.

Reasoning: Investors will want to continue funding our projects if the number of successful projects we have outnumbers the number of failed projects we have. They don't want to lose their money to projects that have no impact on the community, and instead want to fund efforts that have tangible impacts.

Assumption 8: The taxonomic uniqueness metric is negligible aside from the two projects that have a taxonomic uniqueness value of 1.00 (projects with a u value of 1.00 should be prioritized).

Reasoning: Only 2 projects have a taxonomic uniqueness of 1.00, 3 projects have a taxonomic uniqueness of 0.33, and the other 43 projects have a taxonomic uniqueness of 0.67. This means that the uniqueness of these plant species are roughly consistent throughout the imperiled species list, and the uniqueness value is most important for those plant species with a uniqueness value of 1.00.

Assumption 9: The costs of implementing projects do not change over time.

Reasoning: We cannot predict how projects may change over time, but the data provided by the FRPCE gives their best estimates of the funding required to implement each project. Inflation may also result in project costs changing, but inflation rates are unpredictable and relatively small. Our model can be adapted to adjust for different inflation rates, as discussed in the Sensitivity Analysis.

Assumption 10: Our endowment funds will generate investment returns of 8.4% each year.

Reasoning: Although we cannot predict the exact returns in future years, we can use past data to make reasonable estimates. Between 2009 and 2019, the average yearly return of educational institution endowments was 8.4% [2]. Considering the scale of the FRPCE, the organization should have enough resources to emulate similar investing strategies and generate similar returns.

Assumption 11: The FRPCE does not pay taxes on donations, endowment funds, or returns.

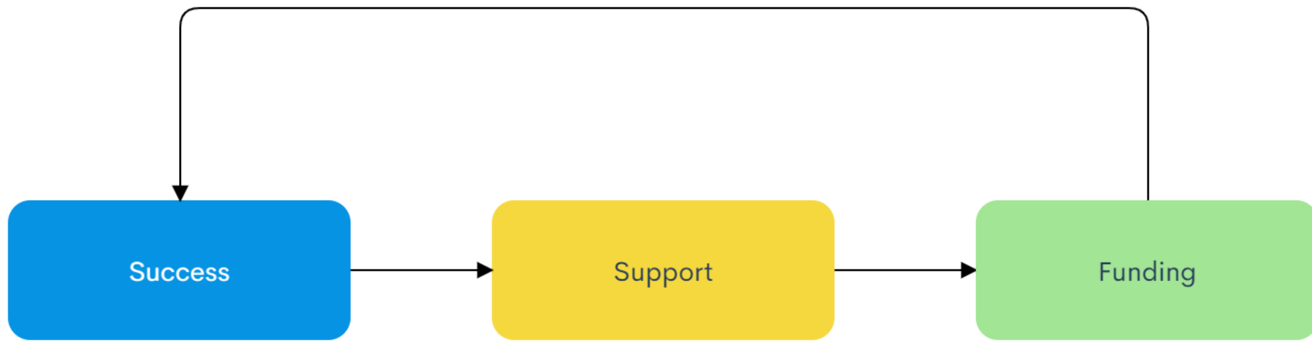
Reasoning: Nonprofit organizations generally do not pay taxes on endowment funds or returns [3]. Given the charitable nature of the FRPCE, they most likely will not have to pay taxes for any of their revenue streams either.

Objectives to Consider + Model Justifications

The objective of this problem is to create a schedule for the conservation projects of the 48 endangered plant species. This schedule should allow for the completion of all 48 conservation projects in a timely manner and should enable us to reliably receive funding for our projects from consistent fundraising efforts.

Part 1: Initial Portfolio/Funding (Length: 5 years)

Because our conservation projects heavily rely on fundraising for funding, we need to demonstrate to our investors that our conservation efforts are both helpful to the environment and are able to succeed. Based on our assumptions, highly successful and beneficial projects will elicit more funding from our investors, which we can use to fund and perform future projects. Additionally, based on Assumption 8, we want to complete the 2 projects that have a taxonomic uniqueness of 1.00 as soon as possible to ensure that these 2 plants have the highest chance of survival. With these objectives in mind, we require some sort of initial portfolio of successful and beneficial conservation projects that signals to our investors that our efforts are worth funding. This short initial phase would last around 5 years, and by the end of the 5 years, we expect a massive amount of support from our investors and the community.



Part 2: Continuous Efforts Plan (Length: 24 years)

The initial wave of support generated from the success of our initial portfolio should provide us with the funding necessary to complete the most expensive projects earlier in the plan. However, in order to continue securing consistent funding for future projects, we need to ensure that no year ends in failure. If there is a year where the majority of projects end in failure (an unsuccessful year, as defined in Assumption 7), we predict that investors and the community may lose confidence in our conservation efforts, and we may not be able to secure funding thereafter. Thus, our primary objective with this plan is to maximize the likelihood of success each year, and later we introduce a pairing algorithm that does exactly this.

Additional Considerations:

We also have to consider the timeframe of our projects when creating our schedule. From Assumption 2, no plant will become extinct before we are able to implement our conservation efforts in a reasonable timeframe. Therefore, there is no rush; however, we still need to create a schedule that is able to complete all the conservation projects within a realistic timeframe. To do so, we will make the timeframe for our schedule as short as possible.

The longest conservation project that we need to complete is 24 years long. A majority of the most beneficial and feasible conservation projects in our list of projects are 3 to 5 years long. Allocating the first 5 years of our schedule to our initial phase of fundraising projects and setting aside the next 25 years to complete the rest of our projects—allowing for the completion of the 24 year long project−gives us a target timeframe of 30 years for our conservation schedule. Combining these objectives allows us to develop algorithms and a mathematical model to determine the schedule for the 48 conservation projects.

Summary of Primary Objectives:

- Create a schedule that organizes when the 48 conservation projects take place.
    - Generate an Initial Portfolio of projects:
        - Projects should be short, beneficial, and likely to succeed
    - Generate a schedule for the remaining projects:
        - Minimize the chances for an unsuccessful year
        - Projects will be implemented within a timeframe of 30 years

Characteristics of Plant Species

There are 4 main characteristics of each plant conservation project that we need to consider when determining our schedule. The characteristics are: the benefit of saving the plants for the environment (if its conservation project is successful), the uniqueness of the composition of plants in the project, the feasibility of the project, and the cost of the project. We also create two additional characteristics that we believe are important in describing each project: the length of the project, and the expected value of the project ($f * b$).

Algorithms/Methods of Model

Initial Portfolio (5 years)

We want our initial portfolio of projects to be made up of the shortest, most beneficial, and most feasible conservation projects. By choosing the most beneficial and feasible conservation projects, we can signal to our investors that our conservation efforts can succeed and are a worthwhile investment of their money. We also need to ensure this portfolio consists of short projects, since our target timeframe for the initial portfolio is 5 years.

In order to determine which projects the initial portfolio should consist of, we devised a metric for ranking the conservation projects by the criteria highlighted in the previous paragraph. We define this metric to be:

$$M_p = \frac{b_p \cdot f_p}{l_p}$$

where M_p is the value of the metric for project p, b_p is the benefit of project p, f_p is the feasibility of project p, and l_p is the length of project p. As we want to maximize benefit and feasibility and reduce project length, a higher value of our metric is desirable. We arbitrarily took the 8 plants with the highest value of M_p and included them in our initial portfolio, as shown below:

Top 8 Plants for our Metric

unique_id	Benefit	Taxonomic Uniqueness	Feasibility of Success	Sum of Costs	Project Length	Metric (b * f / l)
1-Flowering Plants-536	0.99	0.67	0.87	$ 61,931.57	3	0.2871
1-Flowering Plants-514	0.99	0.67	0.99	$ 590,895.51	5	0.19602
1-Flowering Plants-530	0.99	0.33	0.83	$ 407,051.62	5	0.16434
1-Flowering Plants-537	0.66	0.67	0.74	$ 202,118.99	3	0.1628
1-Flowering Plants-481	0.66	0.67	0.72	$ 108,098.39	3	0.1584
1-Flowering	0.49	0.67	0.86	$ 158,873.94	3	0.1404666667

Plants-548						
1-Flowering Plants-502	0.66	0.67	0.60	$ 23,662.72	3	0.132
1-Flowering Plants-179	0.66	0.67	0.97	$ 491,622.77	5	0.12804

We also included the two plants that had a taxonomic uniqueness value of 1.00 in our initial portfolio, for reasons described in Assumption 8 and our discussion of relevant objectives.

Plants With a Taxonomic Uniqueness Value of 1.00

unique_id	Benefit	Taxonomic Uniqueness	Feasibility of Success	Sum of Costs	Length of Project
1-Flowering Plants-133	0.33	1.00	0.60	$ 230,652.28	3
1-Flowering Plants-455	0.66	1.00	0.27	$ 430,879.80	3

These 10 plants in our initial portfolio have lengths of 3 years or 5 years, which is within our target timeframe of 5 years.

Number of Projects	Probability of having exactly this number of successful projects	Probability of having at least this number of successful projects
0	< 0.001%	100%
1	0.006%	99.994%
2	0.098%	99.896%
3	0.906%	98.99%
4	4.802%	94.188%
5	15.207%	78.981%
6	28.685%	50.296%
7	30.73%	19.566%
8	16.478%	3.088%
9	3.088%	< 0.001%
10	< 0.001%	< 0.001%

As seen in the above table, our initial portfolio will generate approximately 5 - 8 successful projects, which should be enough to bolster the board's reputation and generate increased funding.

Calculating the Optimal Schedule of Projects for the Initial Portfolio

Now that we have determined the projects that will go into our initial portfolio, we need to configure the projects optimally to spread out the costs of the projects as evenly as possible. As evenly as possible means minimizing the standard deviation (STD) of all possible configurations of costs per year, as a lower standard deviation means that the values in a distribution are closer to each other.

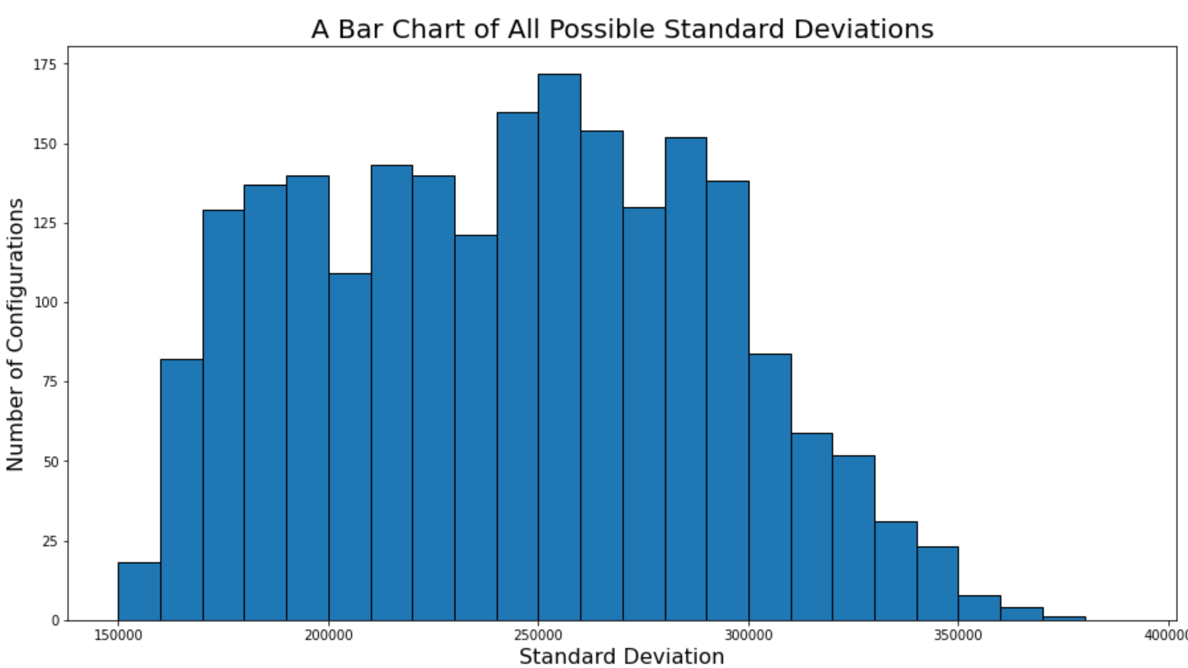
Algorithm: In our initial portfolio, we have 7 projects of length 3 years, and 3 projects of length 5 years. Since we aim to end all of our projects by year 5, there is no flexibility for configuring the 3 projects of length 5 years. However, for each of the other 7 projects, we can: start on year 0 and end on year 3, start on year 1 and end on year 4, or start on year 2 and year on end 5. This means that there are $3^7 = 2189$ possible configurations which we must calculate. In Appendix A, we show the code that demonstrates how we generate the proposed solution (Code format was used in Google Colab).

To search through all configurations of projects and determine the project that has the minimum possible standard deviation, we created a short Python script which is summarized below:

```
minimum_std = MAX_MAX (1e18+)
for possibility in all_configurations:
     if std(possibility) < minimum_std:
          minimum_std = std(possibility)
```
(see Appendix C for full code)

In the above code, *possibility* represents a list of length 5, where each index represents a year's cost (index 0 represents year 1, index 1 represents year 2, etc.). The rest of the code for generating the configurations can be found on the Colab for this project (shown in Appendix A).

Results: We are able to generate all possible standard deviations, as shown below:



According to our algorithm and script, the most optimal configuration of plants is:

Start on Year 1	Start on Year 2	Start on Year 3
1-Flowering Plants-537, 1-Flowering Plants-179, 1-Flowering Plants-514, 1-Flowering Plants-530	1-Flowering Plants-502	1-Flowering Plants-536, 1-Flowering Plants-133, 1-Flowering Plants-455, 1-Flowering Plants-481, 1-Flowering Plants-548

Which becomes:

End on Year 3	End on Year 4	End on Year 5
1-Flowering Plants-537	1-Flowering Plants-502	1-Flowering Plants-536, 1-Flowering Plants-133, 1-Flowering Plants-455, 1-Flowering Plants-481, 1-Flowering Plants-548, 1-Flowering Plants-179, 1-Flowering Plants-514, 1-Flowering Plants-530

The costs for each year end up being:

Year 1	Year 2	Year 3	Year 4	Year 5
$ 540255.35	$ 523589.83	$ 826751.98	$ 435976.49	$ 379213.91

The standard deviation of the above plan is $154377.73, which is the lowest out of all 2187 possible configurations.

At an initial glance, the trends in cost for each year have year 3 as the most expensive, while year 5 has the lowest cost, even though 8 out of the 10 projects end on year 5. When digging a bit deeper into the data, it becomes clear that for each individual project, the cost of the project per year (year 1 cost, year 2 cost, etc.) typically become cheaper as time goes on, perhaps due to improved methods and technology for implementing the conservation projects towards the latter years of the projects.

Continuous Efforts Plan (Year 6 - Year 30)

With the initial portfolio planned out, we need to determine how to schedule the remaining 38 projects over the next 24 years. As explained in Assumption 7, we want to maximize the number of successful years to ensure that we have adequate funding to carry out all of our remaining conservation projects.

Pairing Method

To maximize the number of successful years, we implemented a pairing method, which is created using the following algorithm:

1. Sort the list of remaining projects by feasibility in descending order.
2. Find the break point, which should be halfway between the list.
3. Use that break point to split the projects into two equal-length halves.
4. Take the second half of the list and paste it side-by-side with the first half of the list.
5. Sort only the second half of the list by feasibility in ascending order.

We demonstrate our algorithm with the following 6 conservation projects list example:

unique_id	Feasibility of Success
1-Flowering Plants-452	0.52
1-Flowering Plants-442	0.49
1-Flowering Plants-440	0.38
1-Flowering Plants-173	0.14
1-Flowering Plants-137	0.97
1-Flowering Plants-517	0.24

Step 1: Sort the list of remaining projects by feasibility in descending order.

unique_id	Feasibility of Success
1-Flowering Plants-137	0.97
1-Flowering Plants-452	0.52
1-Flowering Plants-442	0.49
1-Flowering Plants-440	0.38
1-Flowering Plants-517	0.24
1-Flowering Plants-173	0.14

Step 2 and Step 3: Find the break point, which should be halfway between the list. Use that break point to split the projects into two equal-length halves.

unique_id1	Feasibility of Success1
1-Flowering Plants-137	0.97
1-Flowering Plants-452	0.52

1-Flowering Plants-442	0.49

unique_id2	Feasibility of Success2
1-Flowering Plants-440	0.38
1-Flowering Plants-517	0.24
1-Flowering Plants-173	0.14

Step 4: Take the second half of the list and paste it side-by-side with the first half of the list.

unique_id	Feasibility of Success1	unique_id2	Feasibility of Success2
1-Flowering Plants-137	0.97	**1-Flowering Plants-440**	0.38
1-Flowering Plants-452	0.52	**1-Flowering Plants-517**	0.24
1-Flowering Plants-442	0.49	**1-Flowering Plants-173**	0.14

Step 5: Sort only the second half of the list by feasibility in ascending order.

unique_id	Feasibility of Success1	unique_id2	Feasibility of Success2	Probability of One Successful Project
1-Flowering Plants-137	0.97	**1-Flowering Plants-173**	0.14	97.42%
1-Flowering Plants-452	0.52	**1-Flowering Plants-517**	0.24	63.52%
1-Flowering Plants-442	0.49	**1-Flowering Plants-440**	0.38	68.38%

By pairing projects of high feasibility with projects of low feasibility, the probability of there being one successful project within that pair is maximized. This ensures that, for every year where a pair of projects end, that year is most likely successful. By doing so, we can maximize the number of successful years we experience over the course of the next 24 years.

When implementing this pairing method, we also want to make sure no more than one pair of projects end in the same year. The justification for doing this is that we want to ensure there are as many years as possible where investors can see the positive yield of our projects, which will allow us to receive more funding for future projects. Additionally, ending projects in similar years will congregate the costs to a short period of time, meaning that it will be harder to raise the appropriate funds necessary to complete all projects.

Table of All Pairings

unique_id	Benefit	Taxonomic Uniqueness	Feasibility of Success	unique_id2	Benefit	Taxonomic Uniqueness	Feasibility of Success
1-Flowering Plants-452	0.99	0.67	0.52	1-Flowering Plants-135	0.66	0.67	0.42
1-Flowering Plants-528	0.99	0.67	0.57	1-Flowering Plants-492	0.66	0.67	0.29
1-Flowering Plants-551	0.99	0.67	0.56	1-Flowering Plants-426	0.49	0.67	0.31
1-Flowering Plants-122	0.66	0.67	0.99	1-Flowering Plants-508	0.49	0.67	0.1
1-Flowering Plants-553	0.66	0.67	0.65	1-Flowering Plants-517	0.99	0.67	0.24
1-Flowering Plants-127	0.66	0.67	0.49	1-Flowering Plants-546	0.66	0.67	0.49
1-Flowering Plants-560	0.66	0.67	0.87	1-Lichens-567	0.49	0.67	0.14
1-Flowering Plants-520	0.66	0.67	0.73	1-Flowering Plants-186	0.66	0.67	0.21
1-Flowering Plants-486	0.66	0.67	0.71	1-Flowering Plants-436	0.66	0.67	0.22
1-Flowering Plants-476	0.66	0.67	0.67	1-Flowering Plants-480	0.66	0.67	0.23
1-Flowering Plants-558	0.66	0.67	0.75	1-Flowering Plants-173	0.66	0.67	0.14
1-Flowering Plants-168	0.66	0.67	0.59	1-Flowering Plants-475	0.66	0.67	0.27
1-Flowering Plants-415	0.49	0.67	0.61	1-Flowering Plants-485	0.99	0.67	0.25
1-Flowering Plants-442	0.66	0.67	0.49	1-Flowering Plants-507	0.49	0.67	0.43
1-Flowering Plants-519	0.66	0.67	0.52	1-Flowering Plants-440	0.49	0.67	0.38
1-Flowering Plants-524	0.49	0.67	0.53	1-Flowering Plants-176	0.66	0.67	0.38
1-Flowering Plants-529	0.49	0.33	0.53	1-Flowering Plants-557	0.66	0.67	0.36
1-Flowering Plants-543	0.49	0.67	0.57	1-Flowering Plants-513	0.49	0.33	0.29

1-Flowering Plants-137	0.33	0.67	0.97	**1-Flowering Plants-183**	0.66	0.67	0.11

Scheduling Pairs

Now that we have defined our pairing of projects, we need to schedule them optimally. To do so, we devise a second metric which uses the expected benefit (E_p) of each project in the pair:

$$E_p = b_{pA} \cdot f_{pA} + b_{pB} \cdot f_{pB}$$

$b_{pA} \cdot f_{pA}$ is the expected benefit of the first project in the pair, and $b_{pB} \cdot f_{pB}$ is the expected benefit of the second project in the pair.

Now that we've paired up the projects to maximize the number of successful years, we need to schedule the pairs over the course of the 25 years to create a schedule that spreads out the costs of the projects and prioritize higher benefit pairs to start earlier. We prioritize higher benefit pairs to start earlier to ensure that we will have as high support from our investors to fund future projects as possible for each year where project pairs end. To generate a scheduling of the 38 remaining projects that follows the guidelines described earlier, we implemented a greedy algorithm in a Python script, with pseudo-code below:

```
sort list of projects using expected benefit in descending order
for each year up to the last year:
     for each project in the list of projects:
          if length of project can fit in the timeline:
               the project ends on that year
               delete the project from the list of projects
               move on to the next year
```

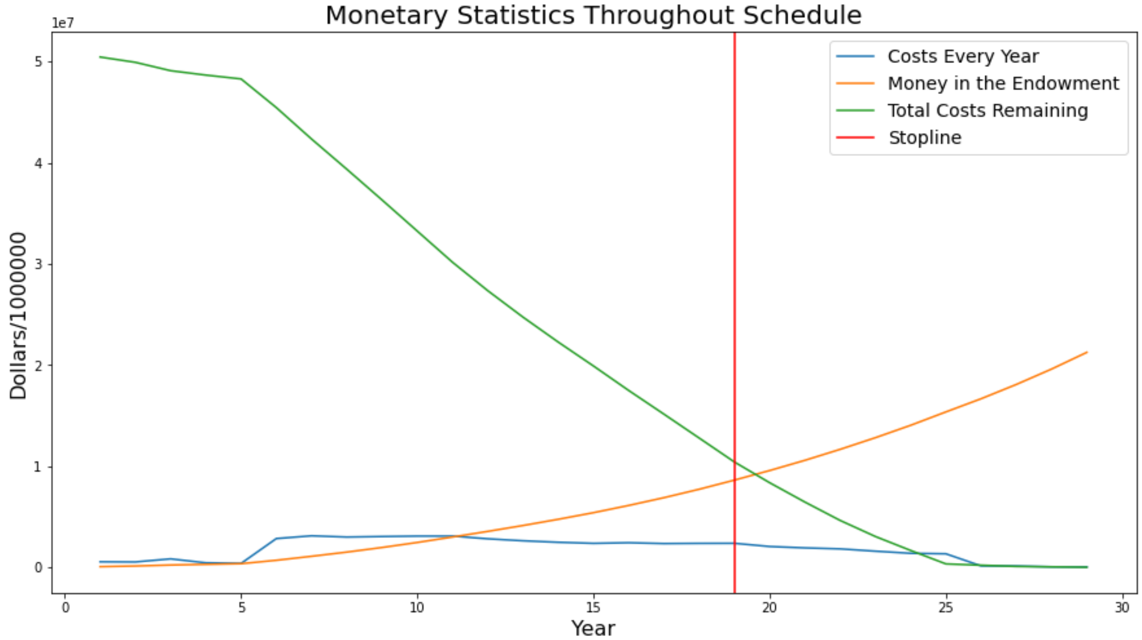
(see Appendix D for full code)

Funding The Schedule

Our schedule provides the optimal solution for all 48 conservation projects to be comfortably funded through traditional fundraising efforts. In addition, in order to help reduce the amount of money required to be raised through traditional fundraising, we propose the following investment strategy.

Each year that our overall conservation efforts are in action, we have some base amount of money that we need to raise to fund all of the ongoing projects in that year. We propose that for each year, the fundraising efforts should aim to acquire 10% more than the base amount of money necessary to fund the conservation project for that year. This extra 10% will then be invested into an endowment that has a yearly interest rate of 8.4%, as described in Assumption 10. We continue the standard fundraising efforts for each year until the year before the amount of money in our endowment exceeds the total amount of money needed by the conservation projects in the remaining years of our schedule. We then fundraise the remaining money needed to cover the gap between the money we have in our endowment and the total amount of funds needed to complete the remaining conservation projects, and use the extra funds we generated to finance the remaining projects.

The justification for this strategy is that we are able to reduce the total amount of money we need to raise from traditional fundraising. We also eliminate the risk of not raising enough money to fund future projects in the last few years of our schedule. Using this strategy, we are able to stop traditional fundraising efforts after year 19 in our 30 year schedule. By doing so, the money we need to raise from traditional fundraising is also decreased and we save $4,557,475.58.



The above graphic depicts our investment strategy for funding our solution. The orange line represents the money we have in our endowment at year y, and the green line represents the total cost of the conservation projects for remaining projects after year y. We stop our traditional fundraising right on the year right before these 2 lines intersect, as their intersection represents the point where we have enough money in our endowment to fund all future projects.

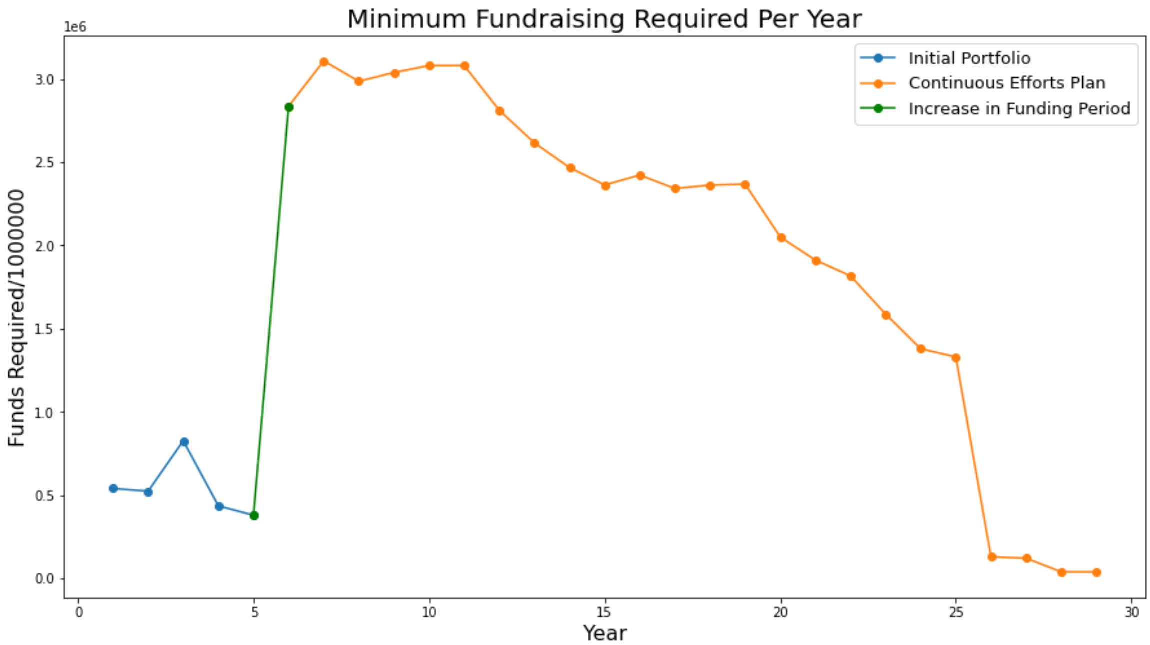
Solutions and Conclusion

Our final solution for how to schedule the conservation projects of the 48 endangered plant species is as follows. Note: 1st year where projects can begin is denoted as year 1.

Starting Year	Projects	Total Cost of Conservation Projects	Fundraising Target	Money to add to Endowment
1	1-Flowering Plants-537 1-Flowering Plants-179 1-Flowering Plants-514 1-Flowering Plants-530	$540,255.35	$594,280.89	$54,025.54
2	1-Flowering Plants-502	$523,589.83	$575,948.81	$52,358.98
3	1-Flowering Plants-536 1-Flowering Plants-133 1-Flowering Plants-455 1-Flowering Plants-481 1-Flowering Plants-548	$826,751.98	$909,427.18	$82,675.20
4		$435,976.49	$479,574.14	$43,597.65
5		$379,213.91	$417,135.30	$37,921.39
6	1-Flowering Plants-137 1-Flowering Plants-183 1-Flowering Plants-452 1-Flowering Plants-492 1-Flowering Plants-560 1-Flowering Plants-551 1-Flowering Plants-173 1-Flowering Plants-122 1-Flowering Plants-415 1-Flowering Plants-186	$2,834,874.38	$3,118,361.82	$283,487.44
7	1-Flowering Plants-135 1-Flowering Plants-553 1-Flowering Plants-517 1-Flowering Plants-127	$3,107,578.58	$3,418,336.44	$310,757.86
8	1-Flowering Plants-476 1-Flowering Plants-486	$2,985,540.44	$3,284,094.48	$298,554.04
9	1-Flowering Plants-168 1-Flowering Plants-507	$3,037,991.00	$3,341,790.10	$303,799.10

10	1-Flowering Plants-480 1-Flowering Plants-528	$3,079,804.49	$3,387,784.94	$307,980.45
11	1-Flowering Plants-475 1-Flowering Plants-546 1-Flowering Plants-519	$3,079,892.02	$3,387,881.22	$307,989.20
12	1-Lichens-567	$2,811,026.16	$3,092,128.78	$281,102.62
13		$2,615,332.49	$2,876,865.74	$261,533.25
14	1-Flowering Plants-442	$2,467,336.35	$2,714,069.99	$246,733.64
15	1-Flowering Plants-436 1-Flowering Plants-426	$2,362,794.15	$2,599,073.57	$236,279.42
16	1-Flowering Plants-440	$2,422,096.50	$2,664,306.15	$242,209.65
17	1-Flowering Plants-558	$2,341,360.84	$2,575,496.92	$234,136.08
18	1-Flowering Plants-508	$2,362,040.37	$2,598,244.41	$236,204.04
19	1-Flowering Plants-176 1-Flowering Plants-524	$2,367,669.19	$1,789,395.92	
20	1-Flowering Plants-557	$2,050,143.26		
21	1-Flowering Plants-485 1-Flowering Plants-543	$1,911,345.62		
22	1-Flowering Plants-529 1-Flowering Plants-513	$1,816,797.11		
23		$1,587,517.11		
24		$1,379,085.23		
25	1-Flowering Plants-520	$1,330,033.06		
26		$129,535.00		
27		$121,522.58		
28		$39,699.02		
29		$39,305.96		
30				

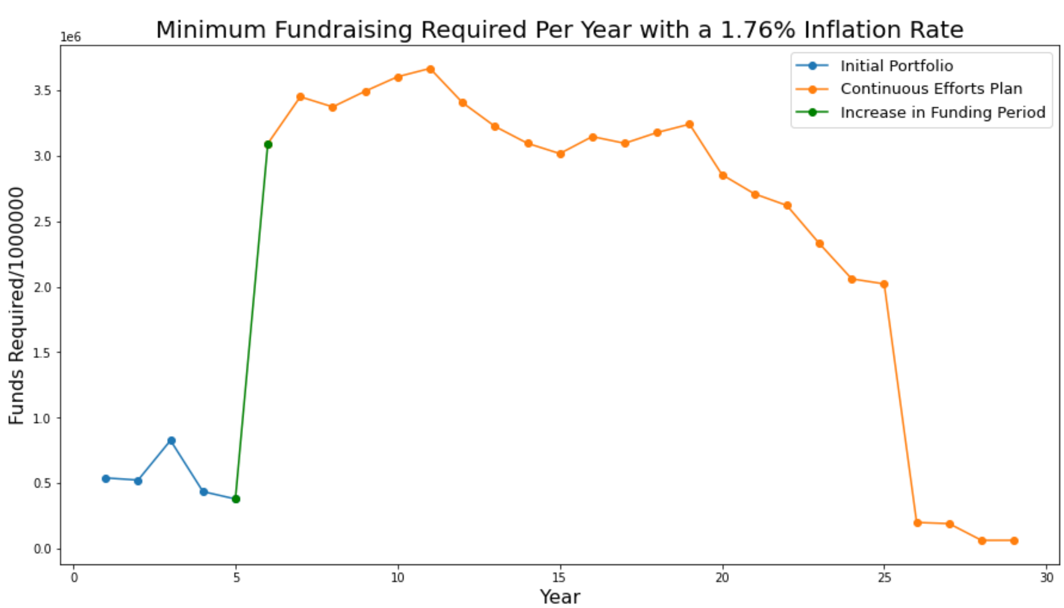
The **minimum** amount of fundraising required each year can be summarized in the graph below (without our generated extra funds):



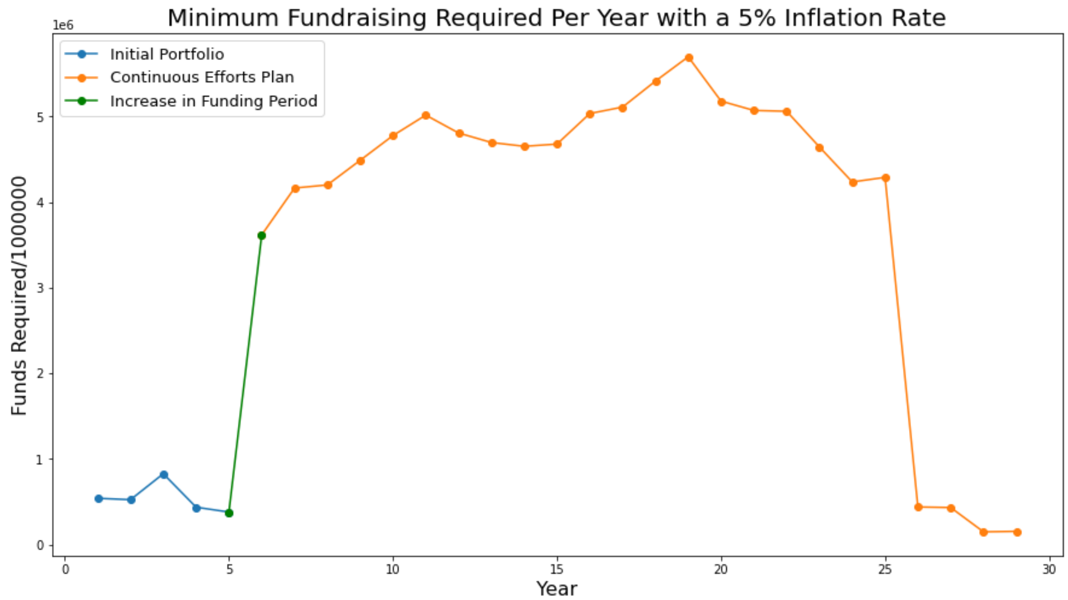
Overall, our solution will allow the board to achieve "long term and reliable" funding by accounting for investors' intentions.

Inflation Sensitivity Analysis

Inflation is a real-world factor that could be taken into account when developing our schedule. Because of the computational nature of our model, we can flexibly forecast the costs for our schedule taking a given inflation rate into account. However, even with inflation, only the amount of fundraising required for each year changes; the schedule of projects itself is consistent.



The above graph illustrates the minimum fundraising required per year when the inflation rate is set to the average inflation rate of the US for the past decade [4].



The inflation rate for the above graph is set at 5%, which would take into account both federal inflation and the potential increase in cost of equipment, personnel, etc. This graph is noticeably different from the cost schedule with no inflation rate and a 1.76% inflation rate, as the cost continues to increase into year 20. Our funding strategies are flexible, however, and provide a solid foundation for what the board should do with different variables.

Model Strengths and Weaknesses

Strengths:

Our model is flexible and code-based, allowing for users to tweak parameters of the model, such as inflation and endowment return rates, and still obtain the most optimal solution. Furthermore, our computational approach and optimization techniques account for all possible schedules that can be created using our techniques, and chooses the option that is most optimal for easy fundraising.

Moreover, our algorithm considers all characteristics of the conservation projects provided to us in the dataset, such as the benefit, taxonomic uniqueness, feasibility, and cost of the projects. We also create some of our own characteristics, such as the length of a project and its expected benefit. By taking into account all of these characteristics, our model is as holistic as possible and is able to provide the board with the most optimal scheduling of plants.

Finally, we take into account real-world intentions involved in fundraising, most importantly the need to build a basis of support from our donors and investors. We designed our mathematical model to take into consideration these real-world intentions, so to make the model as realistic and accurate as possible. We also presented an analysis of other variables, such as investment strategies and inflation, and these variables can be easily adjusted by the board.

Weaknesses:

Our model is based on gaining the trust of donors and investors, and a large part of our model is hinged around the assumption that the projects with a high feasibility value will succeed. Thus, if for some reason multiple projects fail in a row, it may be difficult to raise funds traditionally. In such a case, we would advise that the board should raise funds more slowly and invest more into their endowment, to accumulate more future interest.

References

[1] Smith, Tim. "Endowment." *Investopedia*, Dotdash, 27 April 2020, www.investopedia.com/terms/e/endowment.asp.

[2] Seltzer, Rick. *Endowment Returns' 10-Year Average Rises, but Leaders See Clouds on the Horizon*, Inside Higher Ed, 30 Jan. 2020, www.insidehighered.com/news/2020/01/30/endowment-returns-10-year-average-rises-leaders-see-clouds-horizon.

[3] Maverick, J.B. "Taxing Endowments: How It Works." *Investopedia*, Dotdash, 23 July 2020, www.investopedia.com/articles/fa-professional/090616/taxes-endowments-how-it-works.asp.

[4] "Current US Inflation Rates: 2009-2020." *US Inflation Calculator*, Coinnews Media Group, 12 Nov. 2020, www.usinflationcalculator.com/inflation/current-inflation-rates/.

Appendix

Appendix A: Our Spreadsheet

Link to the Spreadsheet

Appendix B: Our Full Google Colab Code

Google Colab Code

Note: the code is flexible and allows the user to initialize variables easily.

Appendix C: Calculating The Initial Portfolio (without Inflation)

```
!pip install --upgrade gspread #required to read Google Sheets from Drive
from google.colab import auth
auth.authenticate_user()

import gspread
from oauth2client.client import GoogleCredentials

gc = gspread.authorize(GoogleCredentials.get_application_default()) #Connect to
Google Drive. Make sure to authorize the application!

"""Essential data science imports"""
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt

"""Use Gspread to get the information from the spreadsheets"""
ws = gc.open('HiMCM2020ProblemB_ThreatenedPlantsData')
init = ws.worksheet('Initial Portfolio')
init_df = pd.DataFrame(init.get_all_records())

"""Code for finding static costs (projects with length=5)"""
static = ['1-Flowering Plants-179', '1-Flowering Plants-514', '1-Flowering
Plants-530']
init_cost_n = np.zeros([5])
for plant in static:
  for row in range(len(cost_df)):
    if cost_df['unique_id'][row] == plant:
      c = 6
      for x in range(5):
        cost = float(str(cost_df.iloc[row][c]).replace(',', ''))
        init_cost_n[x] += cost
```

```
        c += 1

"""Driver function for calculating costs. Returns a list of costs for each year given
a certain configuration of projects"""
def get_costs(p):
  init_cost = init_cost_n.copy()
  for index in range(3):
    proj_list = p[index]
    for proj in proj_list:
      for row in range(len(cost_df)):
        if cost_df['unique_id'][row] == proj:
          c = 6
          for x in range(index, index+3):
            cost = float(str(cost_df.iloc[row][c]).replace(',', ''))
            init_cost[x] += cost
            c += 1
  return init_cost

"""Code for adding/removing projects"""
def permutations(x, row):
  try:
    p[(x-1)%3].remove(init_df['unique_id'][row])
  except:
    pass
  p[x].append(init_df['unique_id'][row])

p = [[], [], []]
init_cost_list = []
for a in range(3):
  print(a)
  permutations(a, 0)
  for b in range(3):
    permutations(b, 1)
    for c in range(3):
      permutations(c, 2)
      for d in range(3):
        permutations(d, 3)
        for e in range(3):
          permutations(e, 4)
          for f in range(3):
            permutations(f, 5)
            for g in range(3):
              permutations(g, 6)
```

```
                init_cost_list.append(get_costs(p))

min_std = []
for index in range(len(init_cost_list)):
  min_std.append([np.std(init_cost_list[index]), index])

min_std.sort()
print(min_std[0])
```

Appendix D: Calculating The Continuous Efforts Plan (without Inflation)

```
Use the above code block variable initializations

sheet_cost = ws.worksheet('Original')
cost_df = pd.DataFrame(sheet_cost.get_all_records())
plant_list_org = []
cost_list = []
for x in range(len(df)):
  plant_list_org.append([df['Project number'][x], df['Length of pair'][x]])
  cost_list.append((df['Project number'][x], [df['unique_id'][x],
df['unique_id2'][x]]))
cost_dict = dict(cost_list) #Create dictionary

"""Greedy Algorithm"""
plant_list = plant_list_org.copy()
years_list = np.zeros([24])
for year in range(26):
  for plant in plant_list:
    if plant[1] < year+2:
      years_list[year] = plant[0]
      plant_list.remove(plant)
      break

print(years_list) #View the projects that should be completed on each year

"""Driver code for calculating cost"""
cost_list = np.zeros([24])
for index in range(len(years_list)):
  project = years_list[index]
  if project == 0:
    continue #if that year doesn't have a project, skip it
```

```
  p1 = cost_dict[project][0] #project 1
  p2 = cost_dict[project][1] #project 2
  for row in range(len(cost_df)):
    if cost_df['unique_id'][row] == p1 or cost_df['unique_id'][row] == p2:
      time = cost_df['Length of Project'][row]
      c = 6 #Column 6 has year 1 cost

"""Add cost by reverse searching the spreadsheet using the length of the project"""
      for year in range(index-time+1, index+1):
        cost = float(str(cost_df.iloc[row][c]).replace(',', ''))
        cost_list[year] += cost
        c += 1

print(cost_list)
```