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Maximizing Benefits for Women in Delaware: Improving Project Selection Using Optimization Techniques.

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Case Studies
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ABSTRACT

Non-profit organizations need to use scarce resources efficiently. When it comes to helping Delaware women in need, the two most commonly used conservation methods under-achieve this goal. The Rank-Based method, which picks those projects with the highest benefits but ignores their costs, is the current method used by most non-profits but it always brings minimal total benefits. The Binary Linear Programming method, which picks projects to maximize total benefits while ignoring individual project's desirability, leads to maximal total benefits but to the detriment of the average projects' benefits. This paper distinguishes itself from most literature then by showing that optimization can benefit non-profits through tailoring the Rank-Based and Binary Linear Programming methods into a user-friendly, more efficient Hybrid-BLP method. This Hybrid-BLP method leads to a 140% improvement in the number of projects and 112% improvement in total benefits from the Rank-Based method.

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Maximizing Benefits for Women in Delaware:

Improving Project Selection Using Optimization Techniques

Jenna Toussaint, Shang Wu

1. Introduction

Non-profit organizations need to use their resources efficiently. While competitive firms provide some product or service in the hopes of making a profit, non-profits generally have one main goal or mission which can be achieved in a myriad of ways, with different efficiency levels attached to each. From this perspective, the Fund for Women can be seen as an organization that aims to maximize the benefits it provides, but it would like to improve its level of efficiency, given the fact they are constrained by a budget.

The Fund for Women of the Delaware Community Foundation was created in 1993 as a permanent endowment. Its mission is to enhance the worth and potential of women and girls in Delaware, by addressing the unmet needs of this group. They are funded by contributions from private individuals, and currently have a $2.8 million dollar permanent endowment. In the years since its start, it has awarded over $1.4 million in grants to 242 nonprofit programs statewide.

Through the provision of grants relating to the education of girls and women in health, wellness and life skills, it helps this subset of the population avoid abuse and poverty, improves their physical and mental health, and aids in achieving financial independence. Grant awards have also provided prenatal care, housing, abuse counseling, legal assistance, medical care, scholarship programs, and job training. Programs relating to financial literacy, arts enrichment, science and sports programs have also been funded.

Grant applications are made annually on a competitive basis beginning in November of each year, with applications due by January 31 and awards announced in July. There were eleven people in 2010 that reviewed projects and assigned them a score between 1 and 100. The average of these eleven scores, hereafter project score, is used to rank projects from highest to lowest, with projects selected sequentially until funds are exhausted. For 2010, the available budget for funding projects was $130,000.

Limited annual budgets make efficient allocations especially essential. Currently, the program uses a Rank-Based method to select projects. The aim of this paper is to show that the Fund for Women can achieve substantially improved results by using optimization techniques, which are easy to implement and intuitive in nature. In particular, this paper recommends the use of a method known as the Hybrid Selection method to allocate funds among several competing projects.

The remainder of this paper is organized as follows: section one will be a literature review; section two will summarize the data; section three will present the allocations when the program's current Rank-Based method is used; section four will introduce Benefit-Cost Targeting and Binary Linear Programming; section five will present Goal Programming which takes into account both number of people impacted and total benefits; section six will establish the Hybrid Selection method. Finally, section seven will summarize the final recommendations.

2. Literature Review

Linear programming has been used in operations research for the last few decades. In the past it has been used to address problems on a purely theoretical level, while at other times it has been applied to real-world problems. Its applicability extends as far as the airline industry (Marsten et al., 1979), the agricultural industry (Butterworth, 1985), and the research and development field (R&D) (Fox et al., 1984, Blanco et al., 2010) but can also be as commonplace as college class scheduling (Schimmelpfeng and Helber, 2007), football playoffs (Ribeiro et al. 2005) and minor league baseball line-ups.

In Marsten et al. (1979), the authors came up with the novel idea of using integer programming methods to schedule flight crews for airlines. The significance of this early paper lies in the fact there was an improvement in the way the problem was conceptualized and its composition, although the computational aspects of the programming method were not very complex, in comparison to past work.

In the research and development field, Fox et al. (1984) made strides using a binary programming method to deal with present value interactions in R&D. Heidenberger and Stummer (1999) in their paper did a thorough job of detailing the work that has been done in R&D project selection up to that point in time, including a short discourse on the actual methodology behind selection, including scoring and resource allocation. Most recently, Düzgün and Thiele (2010) expounded on the work in R&D project selection, taking a simple binary linear programming model with uncertain coefficients, and using it to ensure the optimization approach was robust when coefficients were allowed to vary.

Butterworth (1985) in his paper almost exclusively deals with the fact that linear programming can be applied easily to farm planning, along with explicit mention of the models and areas where this type of optimization had been applied. Recently, Blanco et al. (2010) utilized a binary linear programming model to solve a problem found in agricultural cooperatives that dealt with minimizing total working time of the machinery.

Optimization has managed to find itself a home outside of industry. Ribeiro and Urrutia (2005) used optimization in a truly unique manner, tailoring integer programming to hobbies like football. Using two different integer-programming models, they were able to know in advance whether teams had qualified for playoffs. Schimmelpfeng et al. (2007), like Ribeiro and Urrutia (2005), applied integer programming to a problem that was more academic albeit conventional, university-course scheduling. This paper aims to add small-scale non-profit organizations to the varied places optimization has been used successfully.

Most non-profit organizations aim to maximize some social benefit given a tight budget constraint. Given a single goal, the simple but powerful Binary Linear Programming method, hereafter BLP, is the first one might think of. The problem with this method however lies in the fact that non-profits do not embrace BLP's outcome, which is maximizing the sum total of benefits subject to the budget constraint. However, non-profit organization, like the Fund for Women rely on the Rank-Based method due to the fact it is easier to understand and implement.

When comparing the two, an operations researcher might choose the BLP as it seems to be the most effective, and does a better job of utilizing the budget. However, the problem with using BLP, from the non-profit organizations' perspective, is that many "best buys" are included in the selection (Messer, 2006). These "best buys" may have small price tags but mediocre benefits, which are necessarily translated as below-average options and ones that the non-profit may not ever have considered choosing. The Rank-Based method, on the other hand, consists of "Cadillac" options, which consist of high-benefit and usually high cost options. Giving due consideration to these two methods, a method which combines the Rank-Based method and the BLP method seems a logical next step (Liu et al., 2011).

The Hybrid-BLP (Liu et al., 2011) method aims to get the best of both worlds - "Cadillacs" and "best buys". There are two reasonable ways the method can be implemented. The first is to apply the BLP method to only a subset of the population deemed "noteworthy" or "above-average"; in this method there can be very little cause for non-profits' retraction. The second is to apply the Rank-Based method for a certain number of options, prior to the budget being maximized, and with the remaining budget, the BLP can be applied again to a subset of the population, as previously mentioned in the latter case. The fact that the Rank-Based method is used means there can be room for flexibility on the part of the non-profits. They can choose to have more or less "noteworthy" versus "Cadillac" projects based on their preferences.

Another method that non-profits might consider would be the Goal Programming method. Hotvedt (1983) used linear goal programming to deal with forest harvest scheduling since forest management required allocating scarce resources to alternative and even competing products. Hotvedt's (1983) primary goals were to optimize total volume harvested, total discounted cash flow, total undiscounted cash flow and total discounted costs. They were each necessary for proper forestry management, however, it was impossible to perform one goal completely without deviating from others. Within this framework, consideration was given to the fact non-profits may not only want benefits to be maximized, but certain areas may need special attention, either due to large population size, or special need, for example, war-torn areas. Gupta et al. (2009) also used goal programming models for the operation of closed-loop supply chains. In their paper they maximize two different profits, one from the net profit for the forward supply chain, and the other net profit from the reverse supply chain.

This paper aims to show that the Hybrid-BLP method, based on its applicability and tailor-made nature, is superior to the BLP and Rank-Based method. Using the Fund for Women, which is a non-profit organization catering to Delaware women's needs, this paper will show the benefits of this new method.

3. Summary Statistics

For the 2010 year, the Fund for Women received applications for 93 projects. The vast majority came from New Castle County; applications from Kent and Sussex County were each about one third of New Castle's. This seems to accurately reflect the population dynamics among the counties.

Table 1 summarizes the key characteristics of the data. Among the eleven graders, scores ranged from a minimum of 5 to a maximum 100, while the project score for the individual projects had a substantially smaller range – its minimum was 39.0 and maximum 94.8.

	Average	Min	Max
Individual Score	70	5	100
Average Score	69.5	39.0	94.8
Amount Requested	$9,899	$1,000	$15,000
No. of People Impacted	467	1	10,000
Kent County Projects	14		
NCC County Projects	44		
Sussex County Projects	15		
Statewide Projects	27		

Table 1: Descriptive Statistics of the Data

Figure 1 summarizes the distribution of grades by each grader. The figure gives a snapshot of the distribution of grades from the 93 projects by each grader; in particular, it shows the minimum, maximum, lower and upper quartile of scores taken from each grader. The minimum and maximum grades are represented by the lower and upper limit of the solid lines. For example, Grader 8 gave at least one of the 93 projects a perfect score of 100, while Grader 11 gave at least one of the 93 projects a score of 70. The lower and upper quartile are represented by the base and ceiling of the boxes, respectively. The lower quartile is obtained by first finding the number that separates the higher half of each grader's scores from the lower half; given the lower half of the grades, again find the number that separates the higher half of the scores from the lower half – this number is the lower quartile. The upper quartile is obtained in a similar way, except the higher half of the of the grades is taken, and the number that separates the higher half of the scores from the lower half from this subgroup is identified as the upper quartile. Thus Grader 7's lower quartile is 30 and upper quartile is 90.

Given this distribution of grades, it would appear that Grader 3 and Grader 11 consistently give high grades; Grader 2 it would appear is also a proficiently higher grader, except for at least one project which he gave a 0. Grader 1 and Grader 9 consistently assign mid-range grades (mid-range anywhere between 50 and 80), while Graders 5, 6, and 7 seem to be the most evenly distributed giving a wider range of scores.

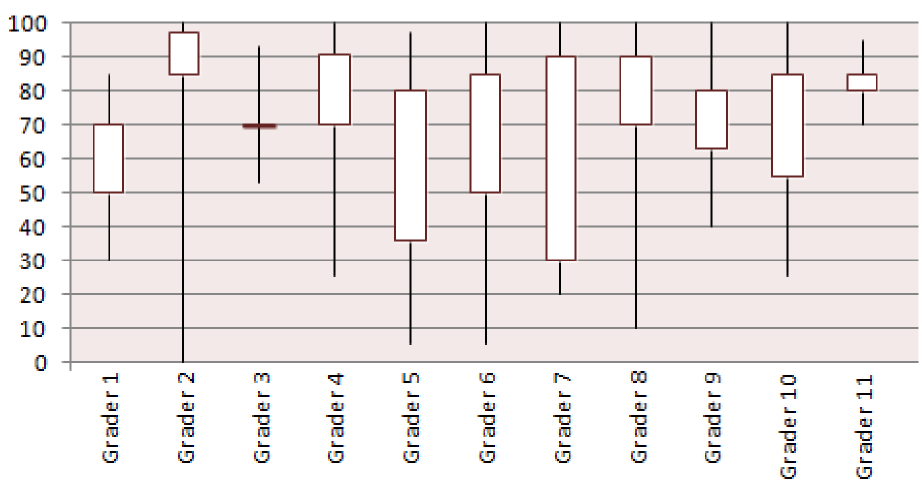

Figure 1: Descriptive Statistics of the Data

4. Rank-Based Methodology (Current Strategy)

The Rank-Based method ranks all projects by project score and awards projects with the highest scores sequentially until the annual budget is exhausted. Table 2 reports the selected projects using this method. The average score for the 10 selected projects which impacted about 10,000 people was 86.24. Two things are worth noting, first, to fund these 10 projects, the Fund for Women went over its budget; second, some projects serve a range of people, not a fixed number, so the maximum, minimum or average could be used to calculate the number of people impacted. For all upcoming analysis, the average number of people impacted will be used.

Formally, the Rank-Based method can be written as follows (Messer, 2006). Let $F(\cdot)$ represent the rank operator over the project benefits V_i. Let $F_i = F(V_1,\ldots V_I)$ be the rank of the *i*th project. The project or projects with the highest benefits receive a rank of one. Let $X_i = \{0, 1\}$, where $X_i=0$ indicates that the ith project is not chosen and $X_i=1$ indicates that the project is chosen. After ranking of all the projects, they are arrayed in the following format:

Rank	Projects	Cost
1	X_i, X_k, X_l	C_i, C_k, C_l
2	X_m, X_n	C_m, C_n
:	:	:
:	:	:
F	X_f	C_f

In situations, where projects have equal rank, the Fund for Women tries to fund the lowest cost project. For example, if projects i, k, and l have the same rank and $C_i<C_k<C_l$, then:

$X_i=1$ if $C_i \leq B$

$X_i=0$ if $C_i > B$

$X_k=1$ if $C_k \leq B-X_iC_i$

$X_k=0$ if $C_k > B-X_iC_i$

$X_l=1$ if $C_l \leq B-(X_iC_i+X_kC_k)$

$X_l=0$ if $C_l > B-(X_iC_i+X_kC_k)$

and so on.

Project #	Project Score	# Impacted	Areas Served	$ Amount Requested	130,000
64	94.80	1,030	NCC	$15,000	$115,000
86	93.36	30	Sussex	$12,000	$103,000
87	86.60	1	Sussex	$15,000	$88,000
78	84.90	1,500	Statewide	$14,375	$73,625
47	84.64	63	NCC	$10,000	$63,625
93	84.40	6,600	NCC	$15,000	$48,625
59	84.36	570	Sussex	$15,000	$33,625
80	84.18	25	Statewide	$15,000	$18,625
58	83.20	315	Sussex	$10,000	$8,625
24	82.00	60	NCC	$14,844	-$6,219
10	862.45	10,194		$136,219	
	86.24				

Table 2: Rank-Based Method Selections

5. Benefit-Cost Targeting and Binary Linear Programming

Binary Linear Programming uses Risk Solver to maximize the aggregate project score (benefits) of all selected projects, subject to the budget constraint. The binary variables should be either 0 (if the project is not selected) or 1 (if the project is selected), and will be multiplied by the project scores to calculate the overall benefits of the selected projects. For example, if Project #24 is selected then by multiplying its project score of 82 by 1, the entire amount can be added into the aggregate project score calculated for the selected projects. If Project #62 is not selected, then by multiplying its project score of 60 by 0, it adds zero to the aggregate project score calculated for the selected parcels.

The basic Binary Linear Programming model is described as follows:

Max: $Z = \sum b_i x_i$

s.t.: $\sum c_i x_i \leq T$

$x_i = 0, 1$

Where x_i is a binary variable indicating whether project i is chosen (1-chosen, 0-not chosen), b_i represents the benefit score as determined by the Fund for Women, and c_i the funding request for project i. T is the total budget available for the selection program for the year. The budget for all upcoming analysis will be $136,219, the amount utilized from their current strategy.

Table 3 reports the selected projects using Binary Linear Programming, hereafter BLP. Under this method, the Fund provides grants for 31 projects, triple the number from their current strategy. The average project score for these 31 selected projects which impacts about 16,000 people is 68.46. The Fund for Women stays within its $136,219 budget under this scenario.

Benefit-Cost Targeting, often recommended by economists, selects projects based on their benefit-cost ratios, where the project with the highest ratio should be acquired first; the project with the second highest ratio should be acquired second, and so forth, until the budget is exhausted (Kaiser and Messer, 2010). This technique is frequently referred to as Cost Effectiveness Analysis in health economics. A project's benefit-cost ratio is calculated by dividing its project score by the amount it requested. For example, Project #63 would be assigned a benefit-cost ratio of 0.08182, as its project score of 81.82 is divided by the amount requested of $1000. Benefit-cost ratios in this case can be taken to mean the project score per dollar.

Table 4 reports the selected projects using Benefit-Cost Targeting (to facilitate interpretation, benefit-cost ratios are multiplied by 1000, thus the benefit-cost ratios shown in the table are the project scores per thousand dollar). Under this method, the Fund again provides grants for 31 projects, triple the number from their current strategy. The average project score for these 31 selected projects which impacts about 16,000 people is 68.10. It is worth noting that the results under this method are very similar the ones derived from Binary Linear Programming; however Benefit-Cost Targeting is easier to understand and execute without the use of proprietary software. [Benefit-Cost Targeting produces similar results to Binary Linear Programming model; however the similarity does not always extend to exactly the same results].

Project #	Project Score	# Impacted	Areas Served	$ Amount Requested
2	43.91	4	NCC	$1,800
4	77.09	120	Statewide	$7,500
5	62.09	500	Statewide	$3,000
6	57.00	100	Kent & Sussex	$5,000
10	64.90	50	NCC	$6,125
12	61.45	4,600	Statewide	$5,000
14	76.70	27	Sussex	$4,000
15	59.36	37	NCC	$5,250
16	69.80	25	Statewide	$3,000
17	59.18	135	Statewide	$2,500
22	70.64	10	NCC	$6,995
28	65.50	68	Statewide	$1,393
31	49.55	8,500	NCC	$3,500
32	74.10	600	Statewide	$5,000
38	78.45	23	Statewide	$5,000
39	35.00	4	Kent	$4,000
42	70.64	33	NCC	$6,865
45	56.64	150	Statewide	$4,550
47	84.64	62	NCC	$10,000
48	64.73	240	NCC	$5,300
49	74.18	67	NCC	$8,000
51	78.45	30	NCC	$5,000
55	79.90	24	NCC	$3,350
56	80.90	13	NCC	$3,600
63	81.82	20	NCC	$1,000
69	72.80	35	Kent & Sussex	$3,603
70	70.20	259	Kent & Sussex	$1,269
71	76.00	313	Kent & Sussex	$1,187
76	73.73	12	Sussex	$2,600
81	72.00	10	Statewide	$3,500
90	81.00	60	Kent	$7,000
31	2122.35	16,131		$135,887
	68.46			

Table 3: Binary Linear Programming Selections

Project #	Project Score per $1000	Project Score	# Impacted	Areas Served	$ Amount Requested	$136,219
63	81.818	81.82	20	NCC	$1,000	$135,219
71	64.027	76.00	313	Kent & Sussex	$1,187	$134,032
70	55.319	70.20	259	Kent & Sussex	$1,269	$132,763
28	47.021	65.50	68	Statewide	$1,393	$131,370
76	28.357	73.73	12	Sussex	$2,600	$128,770
2	24.394	43.91	4	NCC	$1,800	$126,970
55	23.851	79.90	24	NCC	$3,350	$123,620
17	23.673	59.18	135	Statewide	$2,500	$121,120
16	23.267	69.80	25	Statewide	$3,000	$118,120
56	22.472	80.90	14	NCC	$3,600	$114,520
5	20.697	62.09	500	Statewide	$3,000	$111,520
81	20.571	72.00	10	Statewide	$3,500	$108,020
69	20.205	72.80	35	Kent & Sussex	$3,603	$104,417
14	19.175	76.70	27	Sussex	$4,000	$100,417
38	15.691	78.45	23	Statewide	$5,000	$95,417
51	15.691	78.45	30	NCC	$5,000	$90,417
32	14.820	74.10	600	Statewide	$5,000	$85,417
31	14.156	49.55	8,500	NCC	$3,500	$81,917
45	12.448	56.64	150	Statewide	$4,550	$77,367
12	12.291	61.45	4,600	Statewide	$5,000	$72,367
48	12.213	64.73	240	NCC	$5,300	$67,067
90	11.571	81.00	60	Kent	$7,000	$60,067
6	11.400	57.00	100	Kent & Sussex	$5,000	$55,067
15	11.307	59.36	38	NCC	$5,250	$49,817
10	10.596	64.90	50	NCC	$6,125	$43,692
42	10.289	70.64	33	NCC	$6,865	$36,827
4	10.279	77.09	120	Statewide	$7,500	$29,327
22	10.098	70.64	10	NCC	$6,995	$22,332
49	9.273	74.18	68	NCC	$8,000	$14,332
46	9.159	73.27	6	Statewide	$8,000	$6,332
39	8.750	35.00	4	Kent	$4,000	$2,332
31		2110.98	16,076		$133,887	
		68.10				

Table 4: Benefit-Cost Targeting Selections

6. Goal Programming

Fund for Women may want to maximize not only benefits of the projects they select, but also maximize the number of people impacted by the programs they fund. Given this new goal, one should also be aware of the distribution of the Delaware population among its three counties. About sixty percent of Delawareans live in New Castle County, while the remaining forty percent are split equally between Kent and Sussex County.

Goal Programming is an optimization technique employed when trying to achieve multiple competing objectives. Where single-objective optimization, which has been used in all previous analyses, maximizes one objective (total score of selected projects) subject to the budget constraint, goal programming seeks to minimize a weighted sum of deviations from several targets. The key advantage of goal programming over single-objective optimization is flexibility, that is, many new objectives can be added to the model. In particular, the weights on each deviation can be set according to the Fund's preferences. In fact, single-objective optimization is nested within every goal programming model (Kaiser and Messer, 2010).

The Goal Programming model used in this section takes the aggregate project score and total number of people impacted as its two competing objectives. It attempts to find a suitable solution by placing equal weight on each objective. Mathematically, the model is as follows:

i. Objective

Min $d_{SC}^{-} + d_{IM}^{-}$

ii. Constraint

$\sum_{j=1}^{93} x_j \; C_j \leq \$136,219$

$\sum_{j=1}^{93} x_j \; IM_j - d_{IM}^{+} + d_{IM}^{-} = 38,229$

$\sum_{j=1}^{93} x_j \; SC_j - d_{SC}^{+} + d_{SC}^{-} = 2,050$

$x_j, d_{SC}^{-}, d_{IM}^{-}, d_{SC}^{+}, d_{IM}^{+} \geq 0$

Where x_j is a binary decision variable equal to one if project j is selected and zero otherwise; C_j is the amount requested for project j; d^+ and d^- represent positive and negative deviations, respectively. The subscripts correspond to deviations from either the maximum possible aggregate project score of 2,050 or the maximum possible number of people that can be impacted of 38,229. Using this new specification, the model can be run using Risk Solver.

First, consideration is given to equality among counties. That is, an equal number of projects should be selected from every county, where the total number of people impacted and aggregate project score are equally weighted.

Table 5 displays the results of this model. It results in the selection of 20 projects, double the number of projects from the current strategy, and an average project score of 69.50. The number of people impacted is about 38,000, triple the number impacted from the current strategy and about double the number impacted with the single-objective BLP models.

Project #	Project Score	# Impacted	Areas Served	$ Amount Requested
90	81.00	60	Kent	$7,000
6	57.00	100	Kent & Sussex	$5,000
69	72.80	35	Kent & Sussex	$3,603
70	70.20	259	Kent & Sussex	$1,269
71	76.00	313	Kent & Sussex	$1,187
31	49.55	8,500	NCC	$3,500
36	43.70	2,000	NCC	$8,000
64	94.80	1,030	NCC	$15,000
82	78.10	900	NCC	$10,000
93	84.40	6,600	NCC	$15,000
5	62.09	500	Statewide	$3,000
12	61.45	4,600	Statewide	$5,000
17	59.18	135	Statewide	$2,500
28	65.50	68	Statewide	$1,393
32	74.10	600	Statewide	$5,000
45	56.64	150	Statewide	$4,550
57	62.36	10,000	Statewide	$10,456
78	84.90	1,500	Statewide	$14,375
95	73.00	500	Statewide	$10,000
58	83.20	315	Sussex	$10,000
20	1389.97	38,165		$135,833
	69.50			

Table 5: Goal Programming with Equal Selection from Counties

The objective function of the Goal Programming model can be written in its general form as: Min α $d_{SC}^{-} + (1-\alpha)\, d_{IM}^{-}$ where α is a parameter between 0 and 1. It can be interpreted as the relative importance of total project score versus number of people impacted. For example, when α=0.3, it implies that aggregate project score accounts for 30% of the optimal decision, while number of people impacted accounts for 70%. Thus when α=1, aggregate project score is the only factor that matters, and the result will be the same as a single objective of maximizing total project score. Similarly, when α=0, the number of people impacted is the only factor that is taken into account.

Table 6 shows the results of the sensitivity analysis when α is allowed to vary. Notice, as the parameter increases the number of projects chosen and total project score increases, but the number of people impacted falls. Additionally the budget rises as α increase, but starts falling when α reaches 0.9. As the parameter varies from 0 to 0.4, the number of projects selected, total project score, budget and number of people impacted is unchanging and the average project score is also at its highest when α=0.4.

Parameter	Budget	No. of Projects	Total Project Score	Average Project Score	# Impacted	Goal
0	$135,333	19	1,285.95	67.68	38,829	38,229
0.1	$135,333	19	1,285.95	67.68	38,829	34,535
0.2	$135,333	19	1,285.95	67.68	38,829	30,840
0.3	$135,333	19	1,285.95	67.68	38,829	27,146
0.4	$135,833	20	1,389.97	69.50	38,165	23,455
0.5	$135,833	20	1,389.97	69.50	38,165	19,777
0.6	$135,833	21	1,413.77	67.32	38,134	16,102
0.7	$135,883	23	1,587.18	69.01	37,788	12,447
0.8	$135,883	23	1,587.18	69.01	37,788	8,827
0.9	$134,783	26	1,783.46	68.60	36,585	5,264
1	$135,483	30	2,050.10	68.34	15,884	2,050

Table 6: Sensitivity Analysis of Change in Total Project Score and Number Impacted with Equal Selection from Counties

Figure 2 shows the relationship between total project score and number of people impacted when Goal Programming is used. It indicates that it is possible to increase total project score with no tradeoff in number of people impacted (up to a total score of 1800, this holds true). After that point, the tradeoff between score and number of people impacted becomes unavoidable.

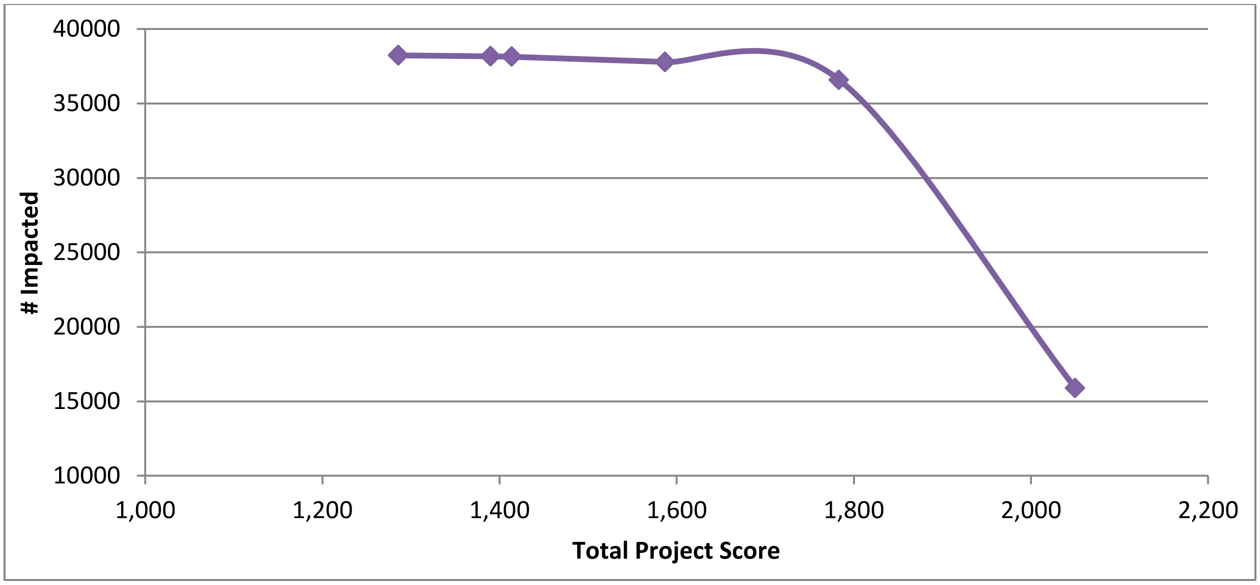

Figure 2: Relationship between Total Project Score and Number Impacted with Equal Selection from Counties

Now, consider appropriating projects based on the population of each county so that New Castle County receives three times as many projects as Kent and Sussex County.

Table 7 shows the result of distributing projects based on relative population size among the counties. A total of 21 projects are selected with an average project score of 68.05, impacting about 38,000. Although total project score has slightly increased from the equal distribution case, average project scores are the lowest of all possible methods used thus far.

Project #	Project Score	# Impacted	Areas Served	$ Amount Requested
39	35.00	4	Kent	$4,000
70	70.20	259	Kent & Sussex	$1,269
71	76.00	313	Kent & Sussex	$1,187
2	43.91	4	NCC	$1,800
31	49.55	8,500	NCC	$3,500
36	43.70	2,000	NCC	$8,000
48	64.73	240	NCC	$5,300
55	79.90	24	NCC	$3,350
63	81.82	20	NCC	$1,000
64	94.80	1,030	NCC	$15,000
82	78.10	900	NCC	$10,000
93	84.40	6,600	NCC	$15,000
5	62.09	500	Statewide	$3,000
12	61.45	4,600	Statewide	$5,000
17	59.18	135	Statewide	$2,500
28	65.50	68	Statewide	$1,393
32	74.10	600	Statewide	$5,000
57	62.36	10,000	Statewide	$10,456
78	84.90	1,500	Statewide	$14,375
95	73.00	500	Statewide	$10,000
59	84.36	570	Sussex	$15,000
21	1429.06	38,367		$136,130
	68.05			

Table 7: Goal Programming with Population-Based Selection

Table 8 shows the results of the sensitivity analysis carried out when selection is based on population. As the parameter increases, reflecting greater emphasis on maximizing total project score, the number of projects increases along with total project score. Predictably, the number of people impacted falls as the parameter increases. Average project score oscillates as the parameter increases, but reaches its maximum when the importance of aggregate project score is 80%.

Parameter	Budget	No. of Projects	Total Project Score	Average Project Score	# Impacted	Goal
0	$135,230	18	1,224.27	68.02	38,455	38,455
0.1	$135,230	18	1,224.27	68.02	38,455	34,732
0.2	$135,230	18	1,224.27	68.02	38,455	31,009
0.3	$135,330	20	1,381.48	69.07	38,389	27,287
0.4	$136,130	21	1,429.05	68.05	38,367	23,592
0.5	$136,130	21	1,429.05	68.05	38,367	19,898
0.6	$135,283	22	1,508.73	68.58	38,278	16,216
0.7	$136,080	23	1,627.85	70.76	38,050	12,554
0.8	$136,080	23	1,627.85	70.76	38,050	8,912
0.9	$136,083	25	1,727.01	69.08	37,544	5,309
1	$136,032	31	2,070.70	66.80	17,926	2,071

Table 8: Sensitivity Analysis of Change in Total Project Score and Number Impacted with Population-Based Selection

Figure 3 shows the relationship between score and number of people impacted when Goal Programming is used. It indicates that it is possible to increase aggregate project score with no tradeoff in number of people impacted (up to a total score of 1800, this holds true). After that point, the tradeoff between score and number of people impacted becomes unavoidable.

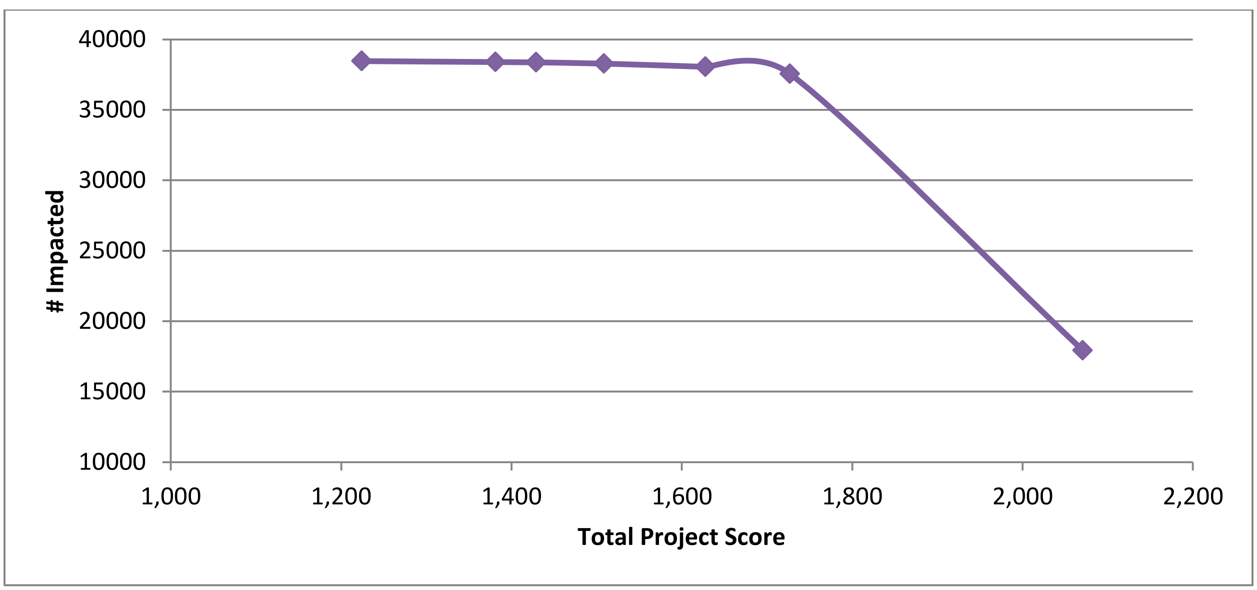

Figure 3: Relationship between Total Project Score and Number Impacted with Population-Based Selection

7. Hybrid Selection Method

There may be concerns when comparing all previous methods with the current Rank-Based method in terms of average project score. The Rank-Based method selects only the best quality projects while the methods shown select one or two highly ranked projects, a large number of mid-range project selections, and several low quality projects resulting in average project scores of around 70, compared to an average project score of 86 from the current method. The hybrid method aims to deal with this phenomenon using a combination of the Rank-Based method and Benefit-Cost Targeting. It can be employed in two ways: the first obtains selections only from those projects that are above the average project score for all projects (average project score is 69.5) using BLP while the second chooses a certain number of projects using the Rank-Based Method and the remainder that are above the average project score (average project score is 69.5) using BLP.

Table 9 shows the result of the first method. Notice, 24 projects are chosen, with an average project score of about 76, and no low quality projects are among those selected.

Table 10 shows the results of the second method when 8 top-ranking projects are chosen. Table 11 shows a comparison among all the methods used. For example, when 9 top-ranking projects are chosen using the Rank-Based method (this is equivalent to the top 9 highest scoring projects, and the remainder using BLP), there is a 50% improvement in the number of projects from the current method, where projects are all high quality, and average project score falling by only 3 points (from 86 to 83). Notice when using the second method, where 10 top-ranking projects are chosen, it is essentially the Rank-Based Method.

Project #	Project Score	# Impacted	Areas Served	$ Amount Requested
47	84.64	63	NCC	$10,000
58	83.20	315	Sussex	$10,000
63	81.82	20	NCC	$1,000
90	81.00	60	Kent	$7,000
56	80.90	14	NCC	$3,600
55	79.90	24	NCC	$3,350
38	78.45	22	Statewide	$5,000
51	78.45	30	NCC	$5,000
82	78.10	900	NCC	$10,000
4	77.09	120	Statewide	$7,500
14	76.70	27	Sussex	$4,000
71	76.00	313	Kent & Sussex	$1,187
7	75.90	20	Statewide	$8,800
49	74.18	68	NCC	$8,000
32	74.10	600	Statewide	$5,000
76	73.73	12	Sussex	$2,600
46	73.27	6	Statewide	$8,000
95	73.00	500	Statewide	$10,000
69	72.80	35	Kent & Sussex	$3,603
81	72.00	10	Statewide	$3,500
22	70.64	10	NCC	$6,995
42	70.64	33	NCC	$6,865
70	70.20	259	Kent & Sussex	$1,269
16	69.80	25	Statewide	$3,000
24	1826.51	3,485		$135,269
	76.10			

Table 9: Hybrid Selection Method – Binary Linear Programming Selection above the Average

Project #	Average Score	# Impacted	Areas Served	$ Amount Requested
64	94.80	1030	NCC	$15,000
86	93.36	30	Sussex	$12,000
87	86.60	1	Sussex	$15,000
78	84.90	1500	Statewide	$14,375
47	84.64	63	NCC	$10,000
93	84.40	6600	NCC	$15,000
59	84.36	570	Sussex	$15,000
80	84.18	25	Statewide	$15,000
63	81.82	20	NCC	$1,000
56	80.90	14	NCC	$3,600
55	79.90	24	NCC	$3,350
14	76.70	27	Sussex	$4,000
71	76.00	313	Kent & Sussex	$1,187
76	73.73	12	Sussex	$2,600
69	72.80	35	Kent & Sussex	$3,603
81	72.00	10	Statewide	$3,500
70	70.20	259	Kent & Sussex	$1,269
17	1381.29	10,532		$135,484
	81.25			

Table 10: 8 Rank-Based with Selection above the Average

Method	No. Chosen from Rank	Average Project Score	No. of Projects	Total Project Score	Budget Required
BLP	0	68.46	31	2,122	$135,887
Hybrid	1	77.95	23	1,793	$135,404
Hybrid	2	77.95	23	1,793	$135,274
Hybrid	3	78.89	22	1,736	$135,409
Hybrid	4	78.21	22	1,721	$135,979
Hybrid	5	79.59	21	1,671	$135,484
Hybrid	6	80.18	20	1,604	$135,484
Hybrid	7	80.43	19	1,528	$135,484
Hybrid	8	81.25	17	1,381	$135,484
Hybrid	9	83.06	15	1,246	$135,781
Rank-Based	10	86.24	10	862	$136,219
Hybrid Method 1	-	76.10	24	1,827	$135,269

Table 11: Comparison of all Methods

8. Final Recommendations

This paper has shown that optimization generally outperforms the Rank-Based method in all aspects but an efficient and worthwhile solution depends on the proper specification of the model. With this in mind, along with the goals of the Fund, the recommendation would be to employ the Hybrid Selection Method using either 8 or 9 high ranking projects. In this case, the tradeoff for funding 5 to 7 additional projects is a slight drop in the current project average by at most 3 points.

For further research it would be useful to have some measure of impact that projects have on the beneficiaries. If there were some measure of impact available, Goal Programming would be an extremely useful tool to ensure that not only the project's score was important but also the level of impact it had on those served.

With this in mind, there may be some concern whether score takes into account the number of people impacted and the extent of the aid. If score takes both into account, the need for an additional measure may not be necessary. Also the use of Goal Programming depends on whether the Fund takes into account the number of people impacted in their choice of the optimal project mix – if they do not, Goal Programming would not bring any benefits to the organization.

Pen ultimately, graders have information on the total budget of projects along with the amount requested. There may be some bias in grading then if total budgets are so large that graders consider the Fund's contribution a "drop in the bucket" leading to negative scoring. Lastly, there may be a possibility that the Fund would like to increase the number of projects that receive funding, such that, number of projects can be added into a Goal Programming Model.

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