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Investment Analysis and Budget Allocation at Catholic Relief Services

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Catholic Relief Services, a not-for-profit agency that funds development programs and humanitarian relief efforts throughout the world, faces a challenging budget-allocation problem annually. We developed a mathematical model and a spreadsheet tool that allocates available funds based on the impact these investments will have in different countries. The model ensures a fair allocation to countries in need that is consistent with the agency's priorities and is simple enough for managers to understand. The agency is using the tool to plan its spending and considers it a success that has greatly improved the planning process.

Key words: decision analysis: applications; finance: investment.

Catholic Relief Services (CRS) was founded in 1943 by the Catholic bishops of the United States; it is the official international humanitarian agency of the US Catholic community, providing humanitarian relief and development assistance in over 90 countries on five continents with nearly 4,000 field staff. Initially CRS helped rebuild Europe during and after World War II, but it has since expanded its relief program to help the poor and disadvantaged and promote development in countries in need all around the world. CRS's current efforts include emergency relief operations for victims of natural and manmade disasters, agriculture programs for poor rural communities, education programs for marginalized populations and women in particular, HIV and AIDS programs for infected people and orphaned children, peace-building programs in areas that are recovering from or are on the edge of violence and war, and community health programs for people with limited or no access to health services.

The agency's expenses in 2003 and 2004 were approximately half a billion dollars annually, with about 50 percent of these expenses going toward relief efforts in response to emergency situations (Table 1). Health, education, and agriculture-development programs also constitute a major part of the agency's activities. CRS supports all these programs from its annual budget, which consists of unrestricted and restricted private contributions and grants from the US government and other public agencies (Table 2). The unrestricted private contributions are donations from the general public to CRS that are not designated for a specific country or relief program. Essentially, the public entrusts these donations to CRS in good faith, and CRS can use them in any way it deems necessary in accordance with its mission statement. The restricted private contributions are also donations from the general public, donated in response to specific relief programs advertised by CRS, and CRS therefore uses them only for that relief effort in the country or countries the donors designate. The US government and other agencies make grants available to CRS in response to its proposal for specific programs. CRS must therefore use these grants in accordance with the framework it agrees on with the contributing agency. The US Department of Agriculture, USAID's Office of Food for Peace, and the UN's World Food Program contribute food commodities, including shipping and handling costs, which combined with other US government and public-sector grants, have constituted more than 75 percent of CRS's total program value in recent years. These programs are highly restricted and closely monitored. In other words, CRS has little discretion as to how to use these resources.

Its unrestricted funds, about $70 million a year, represent about 14 percent of CRS's annual budget and

	2004		2003	
Program area	$ Amount	Percentage	$ Amount	Percentage
Agriculture	72,192	12.59	42,819	8.22
Education	50,371	8.78	42,506	8.16
Emergency	272,329	47.49	272,647	52.36
Fundraising	16,408	2.86	17,667	3.39
Health	40,748	7.11	48,302	9.28
HIV/AIDS	44,343	7.73	23,996	4.60
Management and general	11,026	1.92	9,910	1.90
Peace and justice	21,200	3.70	20,809	4.00
Public awareness	1,999	0.34	2,823	0.55
Small enterprise	11,896	2.07	14,520	2.79
Welfare	31,010	5.41	24,738	4.75
Total	573,495	100	520,707	100

Table 1: Operating expenses breakdown (in alphabetical order) with respect to program area for 2003 and 2004. All amounts are in thousands of dollars.

are not linked to any particular relief or development program. Therefore, it is incumbent on CRS to make responsible investment decisions to maximize the impact of contributors' donations. Specifically, CRS must decide how to allocate these contributions toward ongoing programs in the different countries in which it operates and also in which countries it should initiate new programs. According to CRS's mission statement, these decisions should be based on the needs faced by the people in each country and CRS's ability to respond to those needs.

The annual budget-allocation process of the unrestricted funds at CRS typically took some time and usually involved several discussions, deliberations, and negotiations at various levels throughout the

	2004		2003	
Source	$ Amount	Percentage	$ Amount	Percentage
Contributions				
Unrestricted	75,178	13.62	69,993	14.45
Restricted	33,500	6.07	28,356	5.84
Agricultural	281,324	50.98	261,821	54.06
Cash grants from USG	145,247	26.32	109,128	22.53
All other support	16,586	3.01	15,112	3.12
Total	551,835	100	484,364	100

Table 2: Operating revenues summary with respect to contributing source for CRS for 2003 and 2004. All amounts are in thousands of dollars.

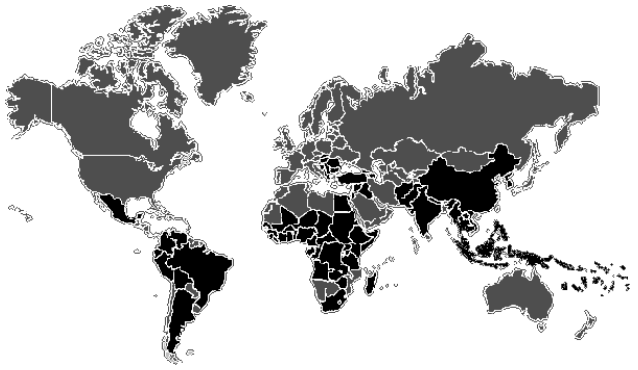

Figure 1: CRS currently has development programs (countries in black) in parts of Central and South America, Eastern Europe, the Middle East, Central and South Africa, and South East Asia.

agency. Given the number of countries (Figure 1) and programs, and the importance of allocating the funds to conform to CRS's mission, the budget-allocation process was challenging for CRS managers. With no sophisticated analytical tools to help them during their decision making and evaluation, the managers suffered frustration and time pressure each year as the allocation period drew near. Moreover, they felt they could improve the final budget allocation to align it more closely with CRS's objectives, to make it consistent from year to year, and perhaps to distribute funds more fairly to countries in need.

CRS wanted a tool to help the managers with the budget-allocation process. They asked us to develop a tool that would synthesize all of the various factors important to CRS, allocate the unrestricted private contributions in a manner consistent with the agency's goals and objectives, and yet be simple enough so that people without extensive mathematical backgrounds could use it and understand it. In addition, they did not want the analysis to be based on past allocations of unrestricted funds. This was a signal of CRS's discomfort with the traditional budget-allocation process and an indication of its willingness to deal with the issue at hand from a clean slate.

We developed a mathematical model and a spreadsheet-based tool that achieves these objectives, and a team at CRS that is responsible for future planning is currently using it. Managers see the tool as a great success because it effectively allocates the available

unrestricted funds according to the agency's objectives through a structured process that is simple and easy to understand.

Model

Our objective was to develop a simple model that would be effective in allocating the budget in a manner closely aligned to CRS's goals. We first evaluated the investment impact in each country and then determined a budget allocation consistent with that impact. The main reason for breaking up the problem in this fashion was to design an approach that was simple and would allow CRS managers to transparently see how the impact of an investment in a country is evaluated.

Investment Impact

Ideally, the members of the managerial team at CRS want to base their decisions on indicators that measure the extent of human suffering with respect to certain factors. At present, when evaluating where to provide assistance, CRS wishes to consider four primary factors: poverty, education, the spread of HIV, and the status of civil liberties. Although these considerations are the primary factors driving its investment allocation decisions, CRS would also like to take into consideration the relative costs of its operations in the various countries to determine what percentage of the money allocated in a specific country is actually spent on helping people in need versus how much is "lost" in operational expenses. Another issue that should enter the decision process when allocating unrestricted private funds is the amount of money that has historically been granted to CRS by the US government or other public-sector organizations (for example, the United Nations) for specific programs in a country (that is, public funding). CRS would like to consider this issue because initial investment from private contributions in a country can serve as the base on which CRS can compete for public grants and promote larger programs in that country. We call this attribute of a country its leverage when making investment decisions.

The underlying assumption that is central to our analysis and consistent with CRS's views on development efforts is that the number of people suffering (with respect to specific factors) in a country is a good indicator of the need to fund development programs in that country. Therefore, to evaluate countries with respect to the four primary factors (poverty, education, HIV, and civil liberties), we looked at data concerning the number of people suffering in different countries throughout the world. Specifically, based on discussions with CRS managers, we used the number of people living on less than \$2.00 a day (United Nations Development Program 2003) as an indicator of the number of people suffering from poverty and the number of recorded HIV infections (United Nations Development Program 2003) as an indicator of the impact of HIV. Also, we used data from Freedom House (2004) to determine the number of people with reduced (or without) civil liberties and the percentage of girls in school (United Nations Development Program 2003) as an indicator of education availability.

Using these data, we compute a need quotient for each country that provides a quantitative measure of its need. Let N be the set of countries to be considered in our budget-allocation analysis, and let F be the set of factors to be considered while evaluating the need of each country. We denote by p_{ij} the number of people in country i suffering from factor j. We provide each of the need factors in F a weight W_j denoting the importance of that factor in comparison to the others. The p_{ij} values, together with the weights W_j, allow us to compute a single scalar, n_i, that represents the need quotient for country i. After several discussions with managers at CRS, we developed three ways of computing n_i that capture a country's need in different ways. In all cases, however, we use the weights W_j to define the agency's views on the importance of the need factors (for simplicity, they sum to 100).

Linear Model: Number of People

Under the linear model for the number of people, we calculate the need quotient for a country as a normalized weighted sum of the number of people in need with respect to the different factors. Specifically, we define the need quotient n_i as follows:

$$n_i = \frac{\sum_j p_{ij} W_j}{\max_i \{\sum_j p_{ij} W_j\}}. \tag{1}$$

We use this model to compute the need of a country based solely on the number of people suffering in

that country, and as a result, it indicates where CRS's investment will affect the most people. The disadvantage of this approach is that a country with a very large population (for example, India) can dominate our impact considerations.

Linear Model: Percentage of People

Under the linear model for the percentage of people, we calculate the need quotient for a country as a normalized weighted sum of the percentage of people in need with respect to that country's total population and the different factors. We denote the total population of a country as P_i and calculate the need quotient as follows:

$$n_i = \frac{\sum_j (p_{ij}/P_i) W_j}{\max_i \{\sum_j (p_{ij}/P_i) W_j\}}. \quad (2)$$

The defining characteristic of this model is that we base the computation of the need of a country on the percentage of people suffering in that country. Therefore, small countries in which a large percentage of the population suffers with respect to any of the primary factors will rate higher than countries with the same number of affected people but larger populations. A potential drawback of this model is that investment impacts are not evaluated according to the number of people that will benefit from relief efforts.

Nonlinear Model

Under this nonlinear model, we first sort the countries in order of decreasing population with respect to each factor in F (the p_{ij} values) and assign a value $s_{ij} = k$ to country i if that country is in the kth position of the list for factor j; s_{ij} serves as a ranking for country i under factor j, and large values of s_{ij} indicate that a country has a greater need than countries with smaller values of s_{ij}. We then define the need quotient of country i as the normalized weighted sum of the ranks s_{ij} with respect to the different factors:

$$n_i = \frac{\sum_j s_{ij} W_j}{\max_i \{\sum_j s_{ij} W_j\}}. \quad (3)$$

This model does not directly gauge the population in need with respect to the different factors when evaluating need in a country but considers the position of this country (based on population in need) compared with all other countries in the analysis. By using this nonlinear model, we avoid the pitfalls presented by the linear models but end up with a need value that is considerably more skewed.

To define the investment impact, we let l_i and c_i denote the leverage and cost of operations, respectively, in country i and compute the investment impact, I_i, for country i as a weighted sum:

$$I_i = W_N n_i + W_L l_i + W_C (1 - c_i), \quad (4)$$

where we assign the weights W_L, W_C, and W_N to the leverage, cost of operations, and need quotient, respectively (for simplicity they sum to 100). These weights allow CRS managers to define the direction of the budget-allocation process in accordance with the agency's policies. Using Equation (4) and substituting the need quotient from (1), (2), or (3), we can get a measure of the impact that a possible investment in any country will have.

Budget Allocation

Once we compute the investment impact for all the countries, we can determine the budget allocation. After some false starts, we concluded that a straightforward approach would work better than more involved models because it would reenforce the managers' intuition and be transparent enough to gain their trust. Specifically, we allocate the budget by looking at the investment impact values and then assigning a percentage of the budget equal to a country's investment impact over the sum of all impacts. In most cases, these nominal allocations are satisfactory. Our only concern with this approach is that these allocations might propose increases in spending that might be too steep or they might suggest a complete withdrawal from a country that is practically infeasible. As a result, we had to develop a mathematical program that ensures that actual budget allocations are as close to the nominal allocations as possible while respecting upper-bound and lower-bound constraints set by CRS managers. We use a nonlinear optimization model with a quadratic objective function to measure the closeness of the actual allocation to the nominal allocation and linear constraints (Appendix).

Implementation

CRS managers use our budget-allocation model with a spreadsheet tool that allows them to effectively plan

the allocation of private unrestricted contributions. This tool is a Microsoft Office Excel spreadsheet that can collect all the necessary input parameters, evaluate and check the data provided, generate the appropriate model, and present the output. The quadratic problem is modeled and solved with Frontline Systems' Premium Solver v6.0 for Excel.

Input Parameters

The main input parameters required in our analysis (Figure 2) are the weights for all the need factors, need quotient, leverage, and cost of operations. The selection of these weights actually forced the managerial team at CRS to rethink and clearly state the agency's programmatic priorities. It also allowed for experimentation with different scenarios and the evaluation of extreme cases in which all but one of the need factors were assigned zero weight. Another set of parameters that has a major impact on the output of the model is the upper and lower bounds on the allocations allowed for each country. We encouraged the managers at CRS to set the bounds based on their experience regarding the kinds of operations that CRS can support in any given country defined as a percentage of the previous year's investment. For example, the upper bound was designated as an indicator of CRS's ability to increase its development effort in a country and was typically set between 150 to 200 percent of the previous year's investment. Similarly, the lower bound served as an indicator of CRS's ability to pull out of a country if necessary.

Output

The spreadsheet tool presents the budget allocations found by using the three need models and the impact for the countries in the analysis grouped in regions (Figure 3). When using the linear model based on absolute numbers of people, the main concern was that countries with very high impact (for example, India) would dominate the allocation of the proposed budget and lead to limited allocations for other countries. However, in practice, the managers at CRS controlled the funds allocated to such outliers by using the upper bounds and overcame this potential drawback. As a result, after many experiments, that model was seen as the clear winner over the other two because it provided the most equitable view of the impact of relief efforts around the world.

CRS is currently using the budget-allocation model and the spreadsheet tool to plan for the remainder of the 2005 budget and for allocations in 2006 based on projected contributions. The managerial team responsible for planning the allocation of unrestricted funds is very happy with the current implementation, confident that the allocations proposed by our model are in direct alignment with CRS's objectives, and, above all, are fair to the people they seek to assist. Moreover, the simple nature of the mathematical model and the ideas behind the tool have allowed managers to understand the inner workings of the model and fully trust the results instead of viewing it as a black box.

Concluding Remarks

Catholic Relief Services must direct the unrestricted contributions it receives from the general public, of about $70 million per year, toward development efforts in more than 90 countries. The allocation of these funds must be done in a fair and simple way that is in alignment with CRS's objective of delivering assistance to people in need. We developed a mathematical formulation and a spreadsheet tool that allocates the available funds based on managers' inputs and according to CRS's mission objectives. We first explored the impact an investment would have based on available data on the number of people suffering with respect to a set of factors, the leverage, and cost of operations in a country. We then developed a model to allocate the budget fairly among the countries considered based on these impact measures. The managers were given the capability to set bounds that limit allocations to each country based on what is practical and a set of weights that are selected to reflect the current agency priorities. The implementation and use of the tool at CRS has been very successful, and it is currently in use for the allocation of future budgets.

One possible extension of this work, in which CRS has expressed some interest, is the allocation of funds not only at a country level but at a program level (for example, to health, education, and other programs). This level of detail presents some new challenges that cannot be addressed by the model in its current form and will require further exploration.

Cells highlighted with this color indicate input fields. input
Cells highlighted with this color indicate errors. error

Country name	Selection	Past investment	Upper bound %	Lower bound %	ABS upper bound	ABS lower bound
Afghanistan	1	1.274	500%	0%	1.000	0.000
Albania	1	0.440	200%	100%	1.000	0.000
Algeria	1	0.000	150%	100%	1.000	0.000
Angola	1	1.836	200%	50%	1.000	0.000
Argentina	0	0.000	200%	100%	1.000	0.000
Armenia	1	0.288	200%	50%	1.000	0.000
Azerbaijan	1	0.138	200%	50%	1.000	0.000
Bangladesh	0	0.000	200%	100%	1.000	0.000
Benin	1	0.615	200%	100%	1.000	0.000
Bolivia	1	0.835	200%	100%	1.000	0.000
Bosnia-Herzegovina	1	0.613	150%	100%	1.000	0.000
Botswana	0	0.000	200%	100%	1.000	0.000
Brazil	1	0.737	200%	50%	1.000	0.000
Bulgaria	1	0.431	150%	100%	1.000	0.000
Burkina Faso	1	0.749	150%	100%	1.000	0.000
Burma	0	0.000	200%	100%	1.000	0.000
Burundi	1	0.586	200%	100%	1.000	0.000
Cambodia	1	0.855	200%	50%	1.000	0.000
Cameroon	1	0.936	200%	50%	1.000	0.000
CAR	0	0.000	200%	100%	1.000	0.000
Chad	0	0.000	200%	100%	1.000	0.000

***Budget*:** 76.062000

	Need	Poverty	Liberties	Female	HIV	Total
Weight	80%	30%	10%	30%	30%	100%

	Leverage
Weight	20%

	Cost of operations
Weight	0%
Total	100%

***Past investments year*:** 2004

***Number of years for leverage calculation*:** 4

***Ranking selection*:** 0

Nonlinear: 0
Linear: 1

Figure 2: The main input page of the spreadsheet tool contains the selection indicators, data on past investments, the upper and lower bounds in percent and absolute forms, the weights for all the need factors, the weights for the leverage and the cost of operations, and the available budget. The budget and past investment amounts are in millions of dollars.

Appendix

Perhaps the most obvious approach to the budget-allocation problem is to use a knapsack formulation. Under this approach, we would maximize the investment impact of the allocation subject to a budget constraint and to possible upper- and lower-bound constraints for the allocation to each country. In our knapsack formulation, the decision variables x_i represent the investment in country i:

$$\text{Maximize} \quad \sum_{i \in N} I_i x_i$$

$$\text{subject to} \quad \sum_{i \in N} x_i = B, \tag{5}$$

$$L_i \le x_i \le U_i \quad \forall\, i \in N, \tag{6}$$

$$x_i \in \mathbb{R}_+ \quad \forall\, i \in N, \tag{7}$$

where I_i is the investment impact for country i, B is the total budget to be allocated, and L_i and U_i are lower and upper bounds on the investment for country i, respectively.

The problem with this model is that it results in a set of countries being allocated their maximum budgets, a set of countries allocated their minimum budgets, and one country allocated funds somewhere between its upper and lower bounds. CRS managers find such a solution unacceptable because it seems inequitable. Consequently, we developed an alternate model that allocates the available budget based evenly on the calculated impact factors. The model is based on the calculation of the nominal allocations denoted as v_i:

$$\text{Minimize} \quad \sum_{i \in N} (x_i - v_i)^2$$

$$\text{subject to} \quad v_i = \frac{I_i}{\sum_{k \in N} I_k} B \quad \forall\, i \in N, \tag{8}$$

$$\sum_{i \in N} x_i = B, \tag{9}$$

$$L_i \le x_i \le U_i \quad \forall\, i \in N, \tag{10}$$

$$x_i \in \mathbb{R}_+ \quad \forall\, i \in N. \tag{11}$$

This model minimizes the differences of the actual allocation amounts x_i from the allocations v_i based

		INVESTMENT IMPACT			BUDGET ALLOCATION (%)		
REGION	**COUNTRY**	**LINEAR #**	**NONLINEAR**	**LINEAR %**	**LINEAR #**	**NONLINEAR**	**LINEAR %**
CARO	Burundi	14.05	59.89	86.77	1.330%	1.606%	2.511%
	Cameroon	7.90	60.94	62.26	1.429%	2.110%	1.820%
	DRC	18.33	86.48	85.07	2.178%	2.178%	2.483%
	Nigeria	23.26	85.72	73.01	2.538%	2.538%	2.125%
	Rwanda	15.43	59.77	77.97	1.361%	1.837%	2.287%
TOTAL		**15.79**	**70.56**	**77.02**	**8.836%**	**10.268%**	**11.227%**
EARO	Eritrea	13.25	48.41	97.44	1.212%	1.302%	2.816%
	Ethiopia	24.67	95.73	90.22	4.078%	3.592%	2.638%
	Kenya	16.90	83.84	63.26	2.031%	3.053%	1.903%
	Sudan	18.21	80.45	77.92	1.408%	2.043%	2.273%
	Tanzania	10.93	75.36	60.77	2.188%	3.120%	1.779%
	Uganda	15.40	73.87	64.55	1.915%	2.985%	1.933%
TOTAL		**16.56**	**76.27**	**75.69**	**12.832%**	**16.095%**	**13.342%**
LACRO	Bolivia	11.82	34.76	42.77	1.140%	1.033%	1.361%
	Brazil	14.22	74.04	31.16	1.452%	1.452%	1.050%
	Dominican Rep.	10.82	34.49	29.23	0.973%	0.359%	0.998%
	Ecuador	8.36	33.28	36.54	1.267%	1.706%	1.127%
	El Salvador	14.76	40.38	53.12	1.178%	1.167%	1.615%
	Guatemala	15.65	57.07	56.24	1.226%	1.571%	1.707%
	Haiti	15.74	69.00	93.01	1.445%	2.312%	2.658%
	Honduras	14.47	42.73	51.33	1.136%	0.965%	1.577%
	Nicaragua	14.46	40.16	63.93	1.213%	1.369%	1.907%
	Peru	11.39	49.43	37.77	1.548%	2.182%	1.191%
TOTAL		**13.17**	**47.53**	**49.51**	**12.579%**	**14.118%**	**15.191%**
SARO	Angola	12.48	70.30	79.35	1.555%	2.649%	2.280%
	Madagascar	16.12	72.86	69.98	1.767%	2.018%	2.077%
	Malawi	15.79	64.03	70.31	1.440%	2.177%	2.088%
	South Africa	10.42	70.08	35.29	1.579%	2.783%	1.141%
	Zambia	12.49	63.59	76.89	1.483%	2.340%	2.247%
	Zimbabwe	11.93	66.08	75.92	1.444%	2.245%	2.235%
TOTAL		**13.21**	**67.82**	**67.95**	**9.268%**	**14.213%**	**12.068%**

Figure 3: The output page of the spreadsheet tool shows the investment impact and proposed allocations for the different models for all the countries in the analysis grouped by geographical region.

purely on the investment impacts for the various countries. Constraint (8) shows how the allocation v_i for country i is computed as a fraction of the budget equivalent to that country's impact over the total impact for all countries in the analysis. These allocations would have been possible without the bounds U_i and L_i, which are enforced by (10). However, we must allow CRS to impose upper bounds when a very steep increase (from previous years) in its efforts would not be practical and lower bounds to allow for a controlled withdrawal of operations from certain countries. Constraint (9) ensures that the allocations proposed will add up exactly to the available budget.

Our model has a quadratic objective function and a feasible set defined by linear constraints. To ensure that a solution exists for the budget allocation model, we specify two conditions for the upper and lower bounds of the allocations: $\sum_{i\in N} L_i \le B$ and $\sum_{i\in N} U_i \ge B$, which we can easily check when the bounds and budget are defined. If these conditions are not met, then the feasible set of the model is empty. Also, it is easy to show that the objective function is convex, and therefore a local optimum will be a global optimum.

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