

Chapter 2

Modeling Approaches and Metrics to Evaluate Nonprofit Operations

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Abstract The Operations Research and Management Science (OR/MS) community is paying increasing attention to the analysis of nonprofit practices, which can significantly differ from for-profit ones. While profit is one of the most widely used performance metrics in for-profit settings, it is not appropriate for nonprofit operations. We start the chapter by suggesting a number of theoretical models that could represent nonprofit operations. Next, we present some strategies used by organizations to align the incentives and objectives of different decision makers participating in the same nonprofit operation. The bulk of the chapter is devoted to bringing to the attention of the humanitarian operations community different candidate metrics valid for measuring nonprofit performance. These metrics are not necessarily unique to nonprofit operations but are used by practitioners and scholars in a large variety of nonprofit situations.

Keywords Nonprofit operations · Performance metrics · Modeling approaches · Managerial practices · Input metrics · Output metrics · Efficiency metrics · Costs · Equity · Equality

2.1 Introduction

This chapter is intended to provide information and references to the humanitarian operations community about a fundamental issue in nonprofit operations: how to measure the performance of an operation when the motivation for its implementation is not for profit. Throughout this chapter, the term nonprofit operation refers to any operation whose objective is not to maximize profit and which has a nondistribution constraint that restricts the feasible solution set. The concept of nondistribution constraint is borrowed from the economics literature, where this constraint ensures that “net earnings, if any, must be retained and devoted in their entirety to financing further production of the services that the organization was formed to

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provide” (Hansmann 1980). In other words, the nondistribution constraint prohibits the distribution of residual earnings to individuals who exercise control over the firm. The existence of this constraint for nonprofit operations is a signal of trustworthiness because it dismisses some of the issues that can be brought when there are informational asymmetries under a for-profit setting. In addition to the existence of this nondistribution constraint, the goal of any nonprofit operation should not be profit, but it is not straightforward to convert the goal into measurable performance metrics. Nonprofit operations can be found in different contexts, such as humanitarian disaster relief, health care or community services. In this chapter we argue that context is important but the examples, strategies, and metrics studied in one applied area can be borrowed by other types of nonprofit operations that can learn and adapt the presented tools to their own contexts.

Multiple papers in the OR/MS literature have proposed metrics to evaluate the performance of generic supply chains or operations (Beamon 1999; Chan and Qi 2003; Shepherd and Gunter 2006), but most of them focus on for-profit cases, suggesting metrics and analyzing examples which revolve around the concept of profit or surplus. To find studies related to nonprofit evaluation one can look at the social science literature (e.g., Carman 2009; Alexander 2010), where these analyses naturally lack an operations’ perspective.

Going back to the OR/MS literature, there is some work studying specific nonprofit performance metrics such as equity (e.g., Savas 1978) or inequality (e.g., Ogryczak 2000). In addition, there is also some literature related to the measurement of performance in specific nonprofit applied areas such as health care (Jacobs 2001) or humanitarian disaster relief (e.g., Beamon and Balcik 2008; Holguín-Veras et al. 2013). However, to the best of our knowledge, this chapter is the first work to provide an OR/MS overview on ways to measure the performance of any nonprofit operation. Because different nonprofit areas share this same challenge, there is value in collecting examples of tools, strategies, and metrics to measure performance from different applied areas. This provides clear value to the humanitarian operations community that is the targeted audience of this volume because it brings new approaches and metrics that can potentially be used in humanitarian operations.

The chapter has the following outline. Section 2.2 provides approaches employed to address issues related to modeling nonprofit operations and finding a common goal for all stakeholders in the operation. Section 2.2.1 compiles multiple theoretical models from the economics and OR/MS literature. Section 2.2.2 presents the best managerial practices that have been used by organizations to align the incentives and objectives of different decision makers participating in the same nonprofit operation. Section 2.3 presents different candidate metrics, some novel to the OR/MS community, for measuring nonprofit performance. These metrics are classified into three groups: input, output, and efficiency metrics. Finally, Sect. 2.4 concludes the chapter with a final example and a summary.

2.2 Modeling Methods and Strategies

The lack of a single common performance metric to measure nonprofit operations is one of the major and most distinctive challenges of this type of operations¹. This challenge is two-fold because there is a lack of a common performance metric that can be used for all nonprofit operations and, at the same time, it is very challenging to find a single performance metric to evaluate a specific nonprofit operation. In addition, this challenge is exacerbated for many nonprofit operations that deal with complex supply chain structures. This complexity can be observed in different ways: the number and different type of participants (e.g., donors, suppliers, providers, volunteers), multiple revenue streams (e.g., donations, grants, fees, subsidies), multiple types of beneficiaries (e.g., those socially excluded), and difficult environments (e.g., difficult to reach areas, warzones).

Giving tools that might help find the right unique performance metric for each operation is not the goal of this chapter. In fact, we argue that this is not the best approach due to the nature of nonprofit operations as previously described. This section offers techniques and strategies to address two issues associated with the lack of having a single suitable performance metric. The first issue (2.2.1) consists of finding the most appropriate theoretical model that better represents the nonprofit operation at hand. The second issue (2.2.2) is related to finding best practices that can favor the convergence to the right common set of performance metrics when dealing with multiple myopic goals. These different goals correspond to multiple agents that have their own metrics and incentives to co-participate in the operation. Next we review literature that addresses these problems.

Modeling the Nonprofit Operation

Easley and O'Hara (1983) provide a formal model of a nonprofit firm that includes the nondistribution constraint and compare the performance of a for-profit and nonprofit firm. In their analysis, the nature of a firm is determined by the contract between the firm and society. Society's objective is to maximize expected social welfare given different allocation mechanisms and the firm's problem is modeled according to the manager's utility. If the selected contract fixes the manager's return then the firm is nonprofit. If the manager's return is unspecified, the firm is for-profit.

In economics, the so-called *profit-constrained firms* are those entities that care about other goals besides profit maximization and that restrict the profit to a specific amount. Sometimes this amount is fixed to zero. James and Rose-Ackerman (1986) refer to three different well-known economic models with a profit-constrained firm structure:

¹ Refer to Berenguer et al. (2014) for an overview of the most recurrent challenges in nonprofit operations and managerial strategies that help address each challenge.

- The Baumol's sales-maximizing firm model assumes oligopolistic markets where the firm attempts to maximize sales subject to a minimum profit constraint (Baumol 1967). The model claims that the oligopolist is in equilibrium at the price and output where realized profit is equal to the minimum acceptable profit.
- The Williamson's model with expense preference maximizes managerial utility subject to a minimum profit constraint (Williamson 1964). The utility function is also called expense preference function and is composed by: salary, status, prestige, and power. The model shows the higher preference of managers for staff expenditure as compared to profit.
- The regulated monopoly by Alchian and Kessel (1962) studies profit-constrained firms and compares the regulated versus unregulated monopolistic market. It claims that the profits of a regulated monopoly can be constrained by the regulatory agency's perception of a "fair" rate of return and the profits of an unregulated monopoly can be constrained by anti-trust actions when having excessive profits.

James and Rose-Ackerman (1986) classify models for nonprofit operations into three sets: maximization of the managers' objective (quality, quantity, product type, revenue, or revenue minus fundraising costs), maximization of an ideological goal subject to survival constraints, and maximization of a strong group's interest.

In the OR/MS field, the domain of multi-objective optimization is suitable to study nonprofit operations because of the lack of a single universal performance metric that could be used for most nonprofit operations. By selecting several (two or more) objectives in our analysis we are inherently stating that the analysis will most likely find a set of solutions that are non-dominated (Daskin 2010). Different methods help identify this set of solutions grouped into the trade-off curve. Some of the most well-known techniques are described in the following lines alongside with each technique's tradeoffs in terms of advantages and limitations.

- The weighted sum method converts the multi-objective problem of minimizing the vector of objectives into a scalar problem by defining a weighted sum of all the objectives. Using a standard optimization method the problem can be optimized. This method cannot guarantee to be able to obtain some of the solutions when the boundary of the feasible set of the problem is non-convex.
- The ϵ -constraint method consists in minimizing one objective and expressing the other objectives in the form of inequality constraints such that the value of each objective has to be smaller or equal than ϵ . This method can identify some of the solutions of non-convex boundaries that the weighted sum method might miss. Disadvantages of this method are the difficulty of selecting a correct ϵ and the use of hard constraints.
- Goal programming seeks to obtain a solution that minimizes the total deviation from the objectives set by management. Different types of mathematical programming models can be used to solve goal programming problems, linear, integer, nonlinear, etc. One of the major disadvantages of this technique is that the solutions found might not be Pareto optimal.

Managerial Strategies

According to scholars studying different types of nonprofit operations, there are some effective best practices that help address the challenges related to dealing with multiple myopic goals by different organizations involved in the same nonprofit operation. For example, Tomasini and Van Wassenhove (2009) and Altay and Labonte (2014) analyze this problem in humanitarian logistics and Kraiselburd and Yadav (2012) study it in the area of global healthcare. These are the main strategies:

1. the establishment of a leading coordinator that coordinates the operation from multiple and sometimes conflicting local objectives to a unified common objective.
2. the pooling of resources to avoid tracking each individual organization's resources and, subsequently, to avoid trying to accomplish different myopic goals in favor of a common overall nonprofit goal.
3. Periodic monitoring of the operation by the production and publication of evaluation reports. The performance metrics monitored and published are very important because they ultimately shape the overall objective of the nonprofit operation, which subsistence depends on the values of these performance metrics.
4. the establishment of high quality information management systems that permit communication between different organizations and thus facilitate effective decision-making.

In the next lines we illustrate strategies (1) and (2) with real humanitarian operational examples.

Example 1: The Role of UNJLC in the Aftermath of Natural Disasters Relief activities in the aftermath of large-scale disasters are usually run by multiple organizations, but collaboration between these organizations does not always occur. Samii and Van Wassenhove (2003) review the disasters in which the U.N. Joint Logistics Center (UNJLC) participated. The UNJLC was a collaborative initiative to share logistic capabilities of cooperating agencies². It was initiated with the outbreak of the civil war in Zaire in 1997, when the World Food Program (WFP) and the U.N. Refugee Agency (UNHCR) had spare capacity in their aircraft which was shared with other relief organizations thanks to the coordination services provided by the UNJLC. From then on, the UNJLC was involved in most of the large-scale humanitarian relief efforts, but there were instances in which collaboration was not always smooth. For example, during the aftermath of the Gujarat 7.9 magnitude earthquake in India in 1981, UNJLC deployed late and left the disaster scene only 4 weeks after arriving. In contrast, the International Federation of Red Cross (IFRC) had its own coordination structure with the Indian authorities but the UNJLC was not in sync with them.

Example 2: HIV/AIDS Crisis in Botswana In 2000 a private-public alliance was launched in Botswana, one of the countries with the highest HIV prevalence rate,

² The UNJLC does not currently exist.

in response to its HIV/AIDs crisis. The founding partners were a pharmaceutical company (Merck) that provides the drugs and part of the funding, the government of Botswana that provides the health infrastructure and resources, and the Bill and Melinda Gates Foundation that provides the other major part of the funds. Within such an alliance, a third party was required to act as the coordinator represented by a multilateral organization, this partner was named African Comprehensive HIV/AIDS Partnership (ACHAP) and it still exists today. Scholars have studied this partnership and claim that the success of the initiative was linked to the role of ACHAP as catalyst and coordinator to the extent that it relieved the other actors from administrative and implementation burdens and “it tried to ensure the accomplishment of system goals” (Rangan et al. 2006).

2.3 Performance Metrics

We now present a list of performance metrics suitable for measuring nonprofit operations’ performance. In measuring this performance, these metrics can be used individually or as part of a multi-objective model. To introduce these metrics we employ a framework based on the simplest representation of an operation: input, output, and efficiency metrics. *Input metrics* refer to the time and the value of the resources needed to run the operation. *Output metrics* are related to the operation’s strategic goal and value the quantity, distribution or quality of product or service produced. Finally, *efficiency metrics* refer to the ability of producing maximum outputs with minimum inputs. From this high level classification we group metrics in subcategories that are common in the performance metrics literature but we also add other metrics that can be especially useful to measure nonprofit operations. For example, in the input metrics category we devote some paragraphs to talk about shortage costs as well as donations and in the output metrics category we pay significant attention to equity and equality measures.

Similar approaches as the one employed in this chapter have been used to study performance metrics in supply chain management in general. For example, Neely et al. (1995) identify two types of measures to evaluate supply chain performance: effectiveness and efficiency. Beamon (1999) classifies the measures in three types: resources, outputs, and flexibility. Chan and Qi (2003) employ a similar approach with three types: inputs, outputs, and composite measures. Gunasekaran et al. (2001) prefer to categorize performance depending on its strategic, operational or tactical focus. Shepherd and Gunter (2006) provide an exhaustive review of articles that study supply chain performance systems and metrics.

The metrics presented in this chapter are selected from the OR/MS field and other fields, such as economics and nonprofit management. Thus, this chapter suggests some specific metrics that have not been considered in OR/MS.

Input Metrics

We follow the generic high-level classification from Chan and Qi (2003) that separate input metrics in costs and time. However, we add donations as an additional input metric that is specific for nonprofit operations. In fact, costs and donations are a very good representation of the resources employed to run a nonprofit operation but cannot represent all input aspects of it. Time is the other key input metric that should be considered to evaluate a nonprofit operation, especially for humanitarian relief-oriented operations.

Costs In addition to considering the regular supply chain costs, managers should study the potential reduction of other costs that are more particular to nonprofit operations such as fundraising and volunteering labor costs. Ben-Ner and Van Hoomissen (1991) detail the main costs of entry and operations of a nonprofit organization (NPO):

- identifying and assembling a collection of stakeholders,
- determining whether collective demand is sufficient to cover costs,
- assembling inputs to produce the goods,
- developing and maintaining a control mechanism to cover stakeholders' interests,
- recruiting managers whose values are expected to cause only agency problems,
- identifying and convincing high-demanders (consumers) that its to their benefit to reveal demands and provide financial support,
- designing mechanisms to discourage stakeholders from free-riding on the activities of others.

In humanitarian relief, Beamon and Balcik (2008) state that the three main costs are the costs of supplies, distribution, and inventory holding. Pedraza-Martinez and Van Wassenhove (2013) highlight transportation costs as one of the most important costs and provide a novel humanitarian fleet management policy that differs from the standard commercial vehicle replacement policy. An empirical analysis shows the potential savings of a policy readjustment.

If a stock-out occurred in some of the nonprofit operations introduced so far, the loss and stock-out costs would be dramatically high because the goods and services provided in these settings are meeting “critical needs” (i.e. needs that are essential to the survival of the population, Nagurney et al. 2009). For example, Pierskalla (2005) studies the supply chain management of blood banks. This chain is simply composed of hospitals that act as blood banks (HBBs), in which patients get the transfusions, and community blood centers (CBCs), where the blood is collected from donors. The authors define the blood shortage costs at the CBCs as the set of costs of processing, handling, and transporting blood in an emergency. The shortage costs at the HBBs are based on the cost of keeping a buffer stock at the site or at other sites.

However, some scholars are studying ways to define stock-out cost in the humanitarian relief context, which valuation goes beyond the purely logistics costs. For example, Holguín-Veras et al. (2013) define the concept of deprivation cost as the economic valuation of the human suffering associated with a lack of access to a good or service. The paper provides some estimation foundations and candidate proxies to measure such costs and claims that the preferred objective function for post-disaster humanitarian logistic models should be social costs, which is the summation of logistic and deprivation costs.

Donations Donations are a type of resource used to run nonprofit operations and are one of the most distinctive features of nonprofit operations. Donations can be in cash or in-kind and can also be exogenous or endogenous. From Weisbrod (2000), exogenous donations “come to the organization essentially regardless of its activities” whereas endogenous donations are “influenced by the nonprofit’s activities.” Managers in nonprofit operations prefer exogenous donations since these funds allow the organization to freely focus on its mission. Volunteering time can be considered an in-kind donation and is typically measured using the estimate wage by which the volunteer labor would be replaced if not donated.

Although donations are freely offered to the nonprofit operation, there are costs related to their management that should be accounted for. For example, volunteering labor might incur costs of recruitment, training, supervision, and retention.

Time Labor is one of the most important resources and it can be measured in time units. This is especially convenient for nonprofit operations because it can indistinctively include paid and volunteer labor. The specific input metric that is most used is hours of labor, which is the number of hours used to produce a good or a service.

Time is a key component in humanitarian operations. These operations can be classified based on whether their main activities are relief or development. Relief activities are short-term activities focused on providing goods and services to minimize immediate risk to human health and survival, whereas development activities are longer-term and focused on community self-sufficiency and sustainability. Thus, time is a critical input factor that should be considered, especially in relief-oriented operations. In particular, speed is the main driver of humanitarian relief operations, where lead time³ reduction facilitates the possibility of increasing speed (Tomasini and Van Wassenhove 2009).

Output Metrics

Output metrics should refer to the operation’s goals and should characterize the quantity, distribution or quality of final product or service produced. Each nonprofit operation is run in a specific context and thus output metrics reflect the nature of

³ Lead time is defined as the time between when a beneficiary order is placed and when it is received.

this context. For example, in the area of health care in developing countries, Yadav (2010) describes several key public health output measures such as mortality, morbidity, life expectancy, quality-adjusted life year (QALY), and disability-adjusted life year (DALY). Nonetheless, in this section we group the output metrics in sets of general metric categories, which can be used in different forms depending on specific applied areas. To facilitate comprehension, some context-specific examples are provided. The output metrics categories reviewed in this chapter are effectiveness, equity, equality, social welfare, and poverty reduction. We should warn the readers that these different categories of output metrics are not always clearly distinct but we believe are the best way to provide a classification of output metrics. For example, some scholars use the notions of equity and equality interchangeably.

Effectiveness Effectiveness is defined as a measure of the level of satisfaction of a need and the alleviation of its adverse impacts (Savas 1978). This measure can be found in multiple forms depending on the domain of application. Next, the use of effectiveness is illustrated in different applied areas in nonprofit operations:

- In the public service field, Savas (1978) suggest the following measures of effectiveness: expected aggregate utility, level of citizen satisfaction, mortality rates, and environmental factors.
- In healthcare in developing countries, Fleßa (2003) studies the optimal allocation of health care resources in Tanzania and suggests five different metrics to measure effectiveness: number of deaths, years of life lost, incidence of disease, prevalence of disease, and loss of quality of life.
- In the education field, Jauch and Glueck (1975) provide an empirical evaluation of the research performance of university professors. The metric employed is the number of publications in respectable journals.
- In humanitarian relief chains, Beamon and Balcik (2008) claim that effectiveness is correlated with metrics such as response time, number of items supplied, and supply availability. Response time is defined as the time between an order and its corresponding delivery. Short response time can be achieved when there is inventory availability and factors such as procurement and distribution are responsive.

In many situations not all beneficiaries can receive the service they need when they need it. Given this allocation problem, a way of defining assignments is by setting up the goal to maximize demand satisfaction or accessibility.

The OR/MS field has extensive work on location and routing analysis with the main purpose of increasing accessibility. If we restrict it to nonprofit operations, the literature is still abundant. For example, in the field of humanitarian logistics, Balcik and Beamon (2008) present a variant of the maximal covering location model to improve response time and the proportion of demand satisfied. In the context of community services, Francis et al. (2006) study the routing efficiency in inter-library loan delivery with a model that describes a period vehicle routing problem (PVRP) and incorporates different levels of service. The objective is a combination of travel times, costs, and service benefits, where service benefits increase if higher

delivery frequencies are selected. In the context of health care in the developing world, mobile facilities can provide care to rural areas. Doerner et al. (2007) present a multi-objective location-routing problem related to mobile facilities in which one of the objectives is to minimize the percentage of the population unable to reach a tour stop within a predefined maximum distance.

In health care, Griffin et al. (2009) study how OR tools can contribute to access to care. They claim that a good management of location of health care facilities, inventory of health products (e.g., blood platelets), and allocation (e.g., organ allocation) are essential to improving this access. Examples of these works are Griffin et al. (2008) that maximize the total weighted demand coverage of needy population served by studying the optimal location, number, and capacity levels of community health centers. A second example is Daskin and Dean (2004) that review location planning formulations in health care, where by accessibility they refer to the ability of patients to reach the health care facility or the health care providers to reach patients.

Equity According to equity theory, human beings believe that rewards and punishments should be distributed according to recipients’ inputs or contributions (see Leventhal 1976). Rawls (1999) studies one of the most popular fairness metrics: the maximum of the minimum individual utility function $\max \min(u_1, \dots, u_n)$, where u_i is the utility function of individual i . This metric represents the maximum of the poorest individual’s utility, but this is one of many other measures of equity proposed in the economics literature.

In the public service literature, Savas (1978) claims that equity is as relevant as efficiency and effectiveness as performance measures. This author states that despite citywide services being efficient and effective, they could be inequitable if all beneficiaries are not treated similarly. Leclerc et al. (2011) review literature that models equity for allocating resources in public service systems with a special focus on the allocation of Emergency Medical Services (EMS). This review contains an interesting discussion on how to construct measures for equity. Balcik et al. (2009) look over the issue of equity in vehicle routing in the nonprofit and public sectors. They provide a summary of equity determinants that is presented Table 2.1.

Table 2.1 Summary of Balcik et al. (2009) sections on applications problems and equity determinants

Application	Equity determinant
Queuing systems	Service waiting time
Resource allocation	Amount of commodities allocated among spatially distributed groups
Workload allocation	Time required to compete tasks
Facility location	Distance between the facility and the group of beneficiaries
Vehicle routing	Arrival time

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