Published in final edited form as:

Health Care Manag Sci. 2016 December ; 19(4): 305–312. doi:10.1007/s10729-015-9328-0.

Creating Impact with Operations Research in Health: Making Room for Practice in Academia

Margaret L. Brandeau, PhD¹

¹Department of Management Science and Engineering, Stanford University, Stanford, CA, USA

Abstract

Operations research (OR)-based analyses have the potential to improve decision making for many important, real-world health care problems. However, junior scholars often avoid working on practical applications in health because promotion and tenure processes tend to value theoretical studies more highly than applied studies. This paper discusses the author's experiences in using OR to inform and influence decisions in health and provides a blueprint for junior researchers who wish to find success by taking a similar path. This involves selecting good problems to study, forming productive collaborations with domain experts, developing appropriate models, identifying the most salient results from an analysis, and effectively disseminating findings to decision makers. The paper then suggests how journals, funding agencies, and senior academics can encourage such work by taking a broader and more informed view of the potential role and contributions of OR to solving health care problems. Making room in academia for the application of OR in health follows in the tradition begun by the founders of operations research: to work on important real-world problems where operations research can contribute to better decision making.

Keywords

Operations research; health care; applications

1 INTRODUCTION

The field of operations research developed during World War II in response to wartime operations and logistics problems. Early operations researchers aimed to apply scientific methods to analyze military operations, and thereby help decision makers optimize the manufacture, deployment and use of manpower and materials to support the war efforts. The stated goal of such early studies was “[to provide] executive departments with a quantitative basis for decisions regarding the operations under their control” [1].

Hand in hand with the development of solutions to these practical problems came the development of theoretical methods to support such solutions [2]. For example, analysis of potential combatant actions led to the development of game theoretic methods; the need to solve large-scale linear optimization problems such as the assignment of ships to routes led

to the development of linear programming; and the need to quantify potential behavior of large-scale complex systems led to the development of computer simulation. Other early applications led to the development of decision analysis, dynamic programming, nonlinear programming, and a variety of methods for routing, sequencing and scheduling, among other methodologies.

Since those early days, operations research (OR) has been applied in a wide range of areas, including business operations management, public services, financial services, marketing, energy and the environment, national security, and healthcare, to name just a few.

Similarly, theoretical tools continue to be developed and expanded, often in response to practical problems. With new and improved algorithms, linear programs can solve problems with tens of thousands of variables. Studies of supply chains have led to theoretical analyses of supply chain coordination, flows of information, and incentives and contracts. Studies of transportation networks have led to numerous theoretical analyses of network design and routing. Studies of healthcare scheduling problems (such as scheduling of patients, nurses or operating rooms) have led to numerous theoretical scheduling models. Studies of newly available “big data” for manufacturing, service and other systems have led to new methods for recognizing and acting on statistically significant patterns in large-scale data.

Too often, however, such theory never influences any decisions. (Full disclosure: I have written quite a few papers of this type.) There are several reasons why this is so.

First, generating analytical results for complex problems often requires strong simplifying assumptions, thus limiting the applicability of the results. Not long ago, a medical colleague who was spearheading an effort to vaccinate tens of thousands of children in China [3] asked me about an issue of vaccine logistics. To help my colleague, I located and reviewed a paper on the topic that was published in a top OR journal. After carefully reading the paper, I realized that the paper provided no insights that could be helpful to my colleague's vaccination effort – even though the paper addressed the same problem he was facing. Because of the simplifying assumptions made in the article, the consequent theoretical results were not applicable to the practical problem.

Second, many problems have been extensively studied, so that sometimes only minor variants remain to be solved. The published scholarly literature contains numerous variations of basic problems in areas such as supply chain management, scheduling, routing, and facility location, to name a few. Although it may sometimes seem “safer” to study a well-established problem, the resulting contribution may be relatively minor and unlikely to influence decisions in any significant way.

Third, academic review and promotion processes at many schools tend to reward the development of theory, rather than successful implementation. As a result, scholars (particularly junior scholars) focus their efforts on theoretical rather than practical analyses; they focus on the development of tools rather than the solution of problems. A Google Scholar search of “nurse scheduling” turns up hundreds of journal articles on this topic – but it is highly likely that no more than a small portion of these studies influenced any nurse scheduling efforts.

Finally, implementation can take a great deal of time. Decision makers need to be fully convinced of the worth of the OR-based solution before they will consider implementing such a solution, and once a decision is made to implement the solution, such implementation can often take a significant amount of time. Because academic review and promotion processes typically assign greater weight to theory than to practice, junior researchers do not want to spend their limited time attempting to work with decision makers in what may be a drawn out and time-consuming process.

How then can OR scholars (particularly junior scholars) be successful in helping decision makers make better decisions? How can scholarly journals, funding sources and senior scholars be more supportive of younger researchers who want to apply OR to influence decisions? The next section discusses my experiences in using OR to inform and influence decisions in health, and the following section provides a blueprint for junior researchers who wish to take a similar path. The subsequent section suggests steps that journals, funding sources and senior scholars could take to better recognize and encourage practical contributions by operations researchers. The paper concludes with a summary of recommendations.

2 MY EXPERIENCES

When I began my research career, I worked on problems in the area of traditional operations management: facility location, network design, operation assignment, capacity planning, and the like. Much of the focus of my work was on the development of theoretical models, but some of the work was implemented in practice [4-6]. The implementations came about through my work as a consultant prior to entering doctoral studies [5], as a graduate student working as a part-time research assistant at Stanford Medical Center [6], and as an assistant professor working with a former student who was a planner at Hewlett-Packard [4].

Then in the mid-1980s, the newly emerging disease AIDS (acquired immune deficiency syndrome) appeared. At the time, AIDS was beginning to be seen in the United States, but little was known about what should be done to control the spread of the disease. Should infected individuals be quarantined? Should the US ban immigration by individuals infected with HIV (human immunodeficiency virus)? Who should be screened for HIV infection – and what control measures should be taken for individuals found to be infected? Policy makers had no clear answers to these and other key questions.

In the rush to control the spread of HIV, policies were often implemented before careful assessment of their likely costs and benefits. “If we could just prevent one infection, it will have been worth it.” This statement by an Illinois state senator caught my eye. The state proposed instituting mandatory HIV screening for all couples seeking to get married in Illinois. How many infections would be prevented and how much would it cost to prevent those infections? And, if we knew the answer to these questions, how would we know if the proposed program was “worth it”? My back-of-the-envelope analysis showed that such a program would likely be quite expensive and prevent few HIV infections. The program was implemented in Illinois in 1988 – but was discontinued in 1989 when the program proved to

be an inefficient use of public health funds. The same funds could have been spent on far more cost-effective HIV prevention programs.

This area of public policy – how to best control the spread of HIV using available (finite) funds – was ripe for OR analysis. The problems are sufficiently complex (nonlinear epidemic spread, multiple means of transmission, variations in individual risk behaviors, uncertainty about the potential effect of programs) that very simple, non-OR-based policy models of the type used by many health policy analysts are not likely to be sufficient for accurately estimating the likely costs and benefits of potential control programs. Moreover, although epidemiologists develop sophisticated and realistic models of epidemics, their focus is generally not on decision making or resource allocation. I realized that there was a promising opportunity for OR to bridge this gap: to develop sophisticated models that accurately reflect HIV epidemic dynamics, risk behaviors and other factors, but that also focus on decision making and choice from among alternative decisions.

Thus began my career applying OR to public health policy. At first I worked only in the area of HIV control, assessing potential HIV control policies such as screening women of childbearing age for HIV, screening newborns for HIV, provision of opiate substitution therapy for injection drug users, expansion of antiretroviral treatment, expansion of HIV screening, and provision of pre-exposure prophylaxis with antiretroviral drugs to uninfected individuals. More recently I have also analyzed policy problems relating to hepatitis B control and problems of public health preparedness planning. The goal of all this work is to provide input that can help decision makers make good decisions.

Of course, shifting my research focus to public health policy while still an assistant professor was risky. I remember our Dean of Engineering asking me at the time, “What does engineering have to do with AIDS?” Although I was taking a risk by moving into this new area, I believed (and still believe) that there was a great opportunity for OR to inform and improve public health decisions. Perhaps most importantly, I was compelled by the many important public health decisions that must be made and inspired by the idea that, by helping to improve decision making in this area, health could be improved and lives could be saved.

To begin work in this area, I realized that I needed to form collaborations with individuals who have knowledge of medicine and public health. Without this domain knowledge, I would not be able to adequately model the decision problems and influence decision making. This was a shift away from the classical OR paradigm I was familiar with, where research on any given project might involve only a few collaborators (for example, a doctoral student and faculty advisor, or a single scholar working alone). Almost all of my projects in public health have involved three or more individuals working together (and typically four or more people). This can be risky for a junior researcher because it is not always easy to identify how much of the work is attributable to any single collaborator on a project – but this information is needed for promotion and tenure evaluations.

Additionally (as is true for many decision problems in the public sector), there is no single decision maker in public health; instead, decisions are typically made by consensus of groups of individuals. Health policy is influenced through a rather diffuse process that

includes publications in well-respected medical and public health journals, meetings with governmental and non-governmental decision makers, and presentation of research findings at scientific conferences and other research venues [7, 8].

As a step toward influencing decisions, I had to learn how to publish the results of my work in medical and other journals that are read by decision makers. Articles published in these journals are very different from articles published in OR journals. Technical details of the OR analysis are typically relegated to a supplemental appendix and, in the main body of the paper, the OR model must be explained in simple terms that non-OR professionals can understand. For example, in a recent paper that evaluated when to initiate antiretroviral therapy (ART) in HIV-infected individuals, we explained our stochastic dynamic programming model as follows [9]: “The approach allows calculations of solutions to complex decision tree models in which every combination of health states – including in this analysis age, CD4 count, and quality of life – is accounted for. For example, a dynamic programming model that tracked age in 6-month intervals between ages 20 and 100 for 7 CD4 cell count categories would be equivalent to a decision tree with 567 health states ($=81 \times 7$). Dynamic programming provides a tractable means of finding optimal solutions of such complex decision problems.”

In the same vein, articles in medical and health journals typically do not include theorems. This means that the junior scholars risk having their publications in these journals dismissed by some academicians as “just an application.” To avoid this potential criticism, in some cases I published the policy results for a given project in a health journal and the technical details of the analysis in an OR journal (e.g., [10, 11]). I also worked to identify interesting theoretical problems arising from the practical problems I was working on. For example, our analyses of the costs and benefits of various HIV prevention programs led to work developing theoretical models for optimal control of epidemics [12-15]; our analysis of how best to control the spread of HIV among networks of individuals with concurrent sexual partners [16] led to theoretical studies of how to model and assess behavior in such networks [17, 18]; and our analyses of hepatitis B catch-up vaccination (vaccinating individuals who did not receive the vaccine at birth) [19] led to the development of a theoretical model for when to stop catch-up vaccination when newborn vaccination rates are increasing over time [20].

Additionally, for articles published in medical and other health journals, the findings from what is often a sophisticated, data- and computation-intensive OR-based analysis must be summarized in a few simple sentences. Some readers may be interested in the nuances of the model results, but most readers would like to understand very simply what the analysis says about potential decisions. Thus, for our study of when to initiate antiretroviral therapy (ART) in HIV-infected individuals, we summarized our nuanced findings (and numerous sensitivity analyses) in this single sentence: “Immediate treatment initiation is optimal for patients under 30 years old regardless of CD4 count under a wide range of assumptions about treatment benefits and harms, while the timing of initiation at older ages depends on the assumed magnitude of the cardiovascular risk from treatment and on patient preferences towards treatment.”

In addition to publishing my work in medical and health journals, I worked to disseminate the findings from my analyses to decision makers at conferences and other scientific venues. This meant attending conferences and meetings that decision makers might attend. For example, our research group has travelled to Russia six times to present our results on injection drug use and HIV infection in Russia and Eastern Europe at an annual conference of Eastern European HIV researchers. We had two of our studies translated into Russian so that they would be more accessible to decision makers in Eastern Europe [21, 22]. I also worked with collaborators who have close ties to public health decision makers [8]. Recently I took a sabbatical in Geneva, Switzerland, working for the Joint United Nations Programme on HIV/AIDS (UNAIDS). This had led to several fruitful collaborations [23-25].

3 APPLYING OR IN HEALTH: A BLUEPRINT FOR JUNIOR SCHOLARS

How can junior scholars who wish to apply OR to health-related problems maximize their chances for success, both in their careers and in influencing decisions? As described below, this involves selecting good problems to study, forming productive collaborations with domain experts, developing appropriate models, identifying the most salient results from an analysis, and effectively disseminating findings to decision makers [8, 26, 27].

3.1 Problem Selection

The problem analyzed must be important to decision makers. Studies of important problems – even studies relying on quick and simple analyses – have a much greater chance of being published and influencing decisions than do studies of relatively insignificant problems, even if the latter studies are very sophisticated and accurate. Collaborators with domain knowledge can help in identifying and framing promising problems for analysis, as they often have a good understanding of which problems are particularly timely and important.

The problem must be one for which an OR-based analysis can add value. Elements of problems that may be particularly suited to OR-based analysis include complexity of the system being analyzed (for example, an emergency department with many simultaneous activities, or an infectious disease that spreads nonlinearly), stochastic elements (for example, variability in patient response to treatment), the need to optimize the system (for example, determining the fastest paths for cardiac patients through a rehab facility), or the need to allocate resources among potential alternatives (for example, allocating a limited number of beds to hospital wards).

The richest problems for analysis have the potential for both practical and theoretical contributions. Analysis and solution of a straightforward scheduling problem may help a decision maker, but may not be viewed by journals, funding agencies or fellow academics as significant (more about them in the following section). On the other hand, analysis and solution of a new type of scheduling problem may help the decision maker and also allow the junior scholar to develop a new theoretical paradigm. This represents OR at its best: the development of new theory motivated by the need to analyze and solve important practical problems.

3.2 Collaboration with Domain Experts

Effective research into health care problems is typically collaborative, as the problems that are most appropriate for OR-based analysis tend to be interdisciplinary and complex. Working with domain experts can help the operations researcher identify and frame important problems for analysis, understand the salient aspects of the problem, obtain needed data, validate the model, and disseminate the results to decision makers.

The best collaborative teams are those in which each person adds value to the project and the team accomplishes more than any single person could accomplish alone. Collaboration with decision makers themselves is ideal, though not always possible. For example, for many problems in public health, no single person is responsible for decision making.

A key barrier that must be overcome by operations researchers who wish to work with health experts is that of convincing the domain experts of the value of OR-based analyses. Many health professionals do not understand what operations research is, nor what it can do. The OR analyst must be able to explain in simple terms how and why OR can add value in solving a practical problem. Explaining potentially complex modeling methodologies such as stochastic dynamic programming or dynamic epidemic models to non-OR professionals may not be easy, but such communication is essential to forming effective collaborations and is an important step in bridging the gap between OR theory and practice.

3.3 Model Development and Analysis

At the heart of any such project is an OR-based model. The model must be simple enough so that it is tractable and has feasible data requirements but detailed enough to capture the salient aspects of the decision problem. Typically there is a tension between domain experts who would like a model to capture as many details of the problem as possible and the OR analyst who needs a tractable, understandable model. Selecting the appropriate type of model to use and striking the proper balance between simplicity and complexity is an art – and the way in which this art is practiced depends on the taste, inclinations and experience of the OR modeler.

In developing the OR model, it is essential to work with domain experts and, if possible, decision makers. Typically, model development is an iterative process: the problem is defined, a simple model is constructed, results are presented and discussed, and additional questions motivate a repeat of the process with a more complex model and/or a further refined analysis. Working with domain experts in this way helps to ensure not only that the model appropriately reflects the decision problem but also that the domain experts understand the model and its outcomes. The latter is an important step toward influencing decisions [8].

“We cannot make a model of this problem because we don't have enough data.” I have heard this statement numerous times. In response, I state that, “Doing nothing is also a decision.” Data are almost always lacking, but this should not necessarily preclude analysis of the decision problem. In our work, we use our best estimates for each parameter to create a base case for our models. Then we perform extensive one-way, multi-way and stochastic sensitivity analyses to determine how the model results are affected by changes in parameter

values and to identify areas where more refined parameter estimates are needed. Sometimes doing nothing is the best solution, but often it is not.

For many types of problems in health care, both quantifiable and non-quantifiable factors are important. Quantifiable factors – which can be estimated using an OR-based model – typically include costs and health benefits (for example, patients seen, infections averted, years of life saved or quality-adjusted years of life saved). Non-quantifiable factors are those stemming from legal, ethical, social and political considerations. It is important to determine qualitatively how these non-quantifiable factors may be affected by each decision alternative. For example, our analysis of potential allocations of incremental ART funding for HIV-infected patients in Russia showed that the most effective and cost-effective allocation would be to allocate all incremental treatment slots to injection drug users. However, such an allocation would be politically unacceptable, so we instead recommended targeting incremental treatment slots to all infected individuals, regardless of drug use status [28]. Failure to recognize non-quantifiable factors can lead to a solution being dismissed as unacceptable by decision makers.

3.4 Identification of Key Findings

Although sometimes difficult, for practical OR-based analyses of health problems it is essential to boil the results of what may be a sophisticated OR-based analysis down to one or two simple statements that provide guidance to decision makers. Such a statement may take the form of “Option A is preferred to Option B” for cases in which several alternative decision options are being considered or, if the results depend on key assumptions about uncertain variables, “Option A is preferred to Option B under these conditions.” For analyses that develop tools for solving a problem, the statement may be that “Our operating room scheduling procedure provides improved solutions for this problem – solutions that are not likely to be attained by manual scheduling methods” or “Our computer simulation model can be used to determine the bottlenecks in this complex process as it evolves and to assess alternative process configurations.”

3.5 Dissemination of Results

As highlighted above, the richest problems for analysis involve a combination of theory and practice. This means that scholars working on such problems have a double burden: in order to influence decision making, they must publish their work in medical and health journals that decision makers will read; and in order to disseminate their theoretical results, they must publish in OR journals and other journals that publish theoretical work. Papers published in health versus OR journals tend to have very different styles, so scholars must learn to present their work in the appropriate style for each type of journal. Similarly, scholars applying OR in health can maximize the dissemination and potential impact of their work by presenting their work not only at OR conferences but also at conferences that decision makers are likely to attend (for example, a hospital administrators conference or a conference on sexually transmitted diseases). Meetings with decision makers, if feasible, also help to maximize the chance that an analysis will have influence. In all cases, being able to communicate results in simple terms is essential.

It is often useful to communicate the results of an analysis outside of scientific venues. This can be done, for example, by issuing press releases when a study appears, speaking with members of the press, writing for more publicly oriented publications, and blogging. Such skills require study and practice to master. Academics are often uncomfortable with such skills initially but these forms of communication can be mastered and are highly valuable in disseminating findings.

4 MAKING ROOM FOR PRACTICE: THE ROLE OF JOURNALS, FUNDING AGENCIES AND ACADEMIA

How can journals, funding agencies and senior scholars in academia encourage impactful work of the type described above, and how can junior scholars be part of this process?

4.1 Role of Journals

As described above, it is important for junior scholars to publish their work in OR journals, but also in health and medical journals as appropriate.

To publish in health and medical journals, junior scholars must be able to describe their models and findings in terms that the readers of those journals will understand; technical details of the model and analysis can be included in an appendix. This involves striking the right balance in the main body of the paper between providing enough detail of the OR methods so that it is clear how the problem was modeled and analyzed, but not so much detail that readers will not understand the exposition. Health and medical journals have become increasingly receptive to model-based analyses. It is up to OR scholars to present their work in a way that convinces editors and reviewers of these journals of the worth of their work.

Similarly, for OR journals, junior scholars working on OR in health must present their work in an appropriate format – one that emphasizes both theory and practice. Here journal editors and reviewers can play a key role in encouraging such work. They can do so by taking a broad view when assessing the contribution of a paper, evaluating not only the development of new theory and models but also the application impact of the work. Editors can select reviewers who have an appreciation of practical analyses. Editors can commission special issues devoted to practical analyses. Such changes can encourage a culture that values the solution of practical problems.

In addition to journals that focus on health and medical studies and journals that focus on OR-based studies, some journals embrace both types of work. For example, journals such as *Health Care Management Science* aim to include both medical policy papers and OR-based analyses.

4.2 Role of Funding Agencies

Junior scholars and funding agencies can both take steps to facilitate funding of OR-based analyses of important healthcare problems.

Funding for such work may come from a variety of sources including traditional OR funding agencies (e.g., National Science Foundation), health funding agencies (e.g., National Institutes of Health), foundations (e.g., Bill and Melinda Gates Foundation), and healthcare providers (e.g., a hospital or clinic), so junior scholars must cast a wide net when seeking out potential funding sources. In grant proposals, junior scholars must be able to articulate not only the importance of the problem they propose analyzing, but also how and why OR is appropriate for the analysis. Problem importance is paramount, but a clear description of the proposed OR analyses is also essential. For proposals submitted to health funding agencies, junior scholars may also have to explain what operations research is. Indeed, the term “operations research” is often used by health funding agencies to narrowly mean research into operations (e.g., examination of the number of patients lost to follow up in different stages of HIV care), rather than the broader meaning used in the OR community that includes complex systems modeling, optimization, and other forms of analysis. Additionally, proposals that include domain experts as part of the research team are significantly more likely to be funded than proposals with a research team comprised solely of operations researchers.

Funding agencies can encourage such work in a number of ways. They can issue calls for proposals on model-based, interdisciplinary analyses of important problems, as is increasingly done. They can also create review panels that include reviewers who are knowledgeable about modeling in general and operations research specifically. In my experience, unqualified, non-modelers are often assigned to review proposals involving OR analyses in health. For example, I have seen reviews of proposed OR analyses that criticize the proposal because it does not include hypotheses – but hypotheses are typically irrelevant to OR-based analyses. I have also seen reviews of OR-based proposals with serious methodological flaws that were not identified by unqualified reviewers. Funding agencies need to find reviewers who can understand and appreciate operations research and its potential contributions to informing health care decision making. In the same vein, funding agencies need to find reviewers who have a broad perspective on modeling, rather than a very narrow perspective (“Why aren't you using my favorite modeling technique?”). Members of the OR community can help to ameliorate these problems by participating as proposal reviewers, particularly for health funding agencies where reviewers with OR expertise are scarce.

4.3 Role of Academia

Junior scholars respond well to incentives. The current system of promotion and tenure at many universities rewards the development of theory, rather than practice, so junior scholars often gravitate toward theoretical rather than practical studies of health care problems. As argued above, however, theory and practice need not be mutually exclusive. Although extra effort is involved, work on both theoretical and practical problems can enrich a junior scholar's portfolio of accomplishments.

Senior scholars who evaluate the work of junior scholars can encourage practical work in a number of ways. They can educate themselves about relevant non-OR journals: for example, understanding the mission, quality, acceptance standards and impact of various health and

medical journals. As an example, the journal *Annals of Internal Medicine* [29] has an impact factor of 16.1 (this is the average number of times than an article published in the journal within the last two years is cited in other papers), while the journal *Operations Research* [30] has an impact factor of 1.5. A senior OR scholar with little knowledge of health and medical journals might dismiss a publication in such a medical journal as unimportant when in fact the article might have high visibility and potential impact. Additionally, in promotion and tenure cases, the interdisciplinary nature of health care OR must be recognized. This means selecting suitable evaluators for the candidate, including not only scholars in operations research and management science, but also individuals with expertise in areas such as health care, medicine, or public health. This also means taking steps to identify the junior scholar's contribution to collaborative projects. Some journals make this clear with a statement of the contribution of each author on a published paper. In some cases, if coauthors of a study have clearly defined expertise (e.g., an OR modeler or a physician), the contributions of different individuals may be easy to identify. In other cases, contributions can be identified by polling the coauthors of an article. Finally, it is important to develop a culture of promotion and tenure that recognizes that not all good work involves theorems: simple models that have impact can often be more meaningful than abstract and complex theoretical models.

5 CONCLUSIONS

As highlighted in this article, junior scholars as well as journals, funding agencies, and senior academics can all play a role in making room in academia for the application of OR in health care. Junior scholars can maximize their chances of success in this area by focusing on problems of importance, collaborating with domain experts, developing both theory and practice, and effectively communicating the results of their analyses to both OR and non-OR audiences. Journals, funding agencies, and senior academics can encourage such work by taking a broader and more informed view of the potential role and contributions of OR to solving health care problems. Decisions about many important health care problems could be improved with input from OR-based analyses. By making room in academia for practical OR analyses in health, we will be encouraging junior scholars to help solve important problems – and we will be returning to the original spirit of operations research.

Acknowledgment

This work was supported by Grant Number 1-R01-DA15612 from the National Institute on Drug Abuse.

Funding Source: Margaret Brandeau was supported by Grant Number 1-R01-DA15612 from the National Institute on Drug Abuse.

References

1. Morse, PM.; Kimball, GE. Methods of operations research. 1st revised ed.. MIT Press & J Wiley; Cambridge: 1954.
2. Gass SM. Great Moments in HistORy. *OR/MS Today*. 2002; 29(5):31–37.
3. Chen JJ, Chang ET, Chen YR, Bailey MB, So SK. A model program for hepatitis B vaccination and education of schoolchildren in rural China. *Int J Public Health*. 2012; 57(3):581–588. [PubMed: 21845405]
4. Billington, C.; Brandeau, ML.; inventors. System and method for optimum operation assignments in printed circuit board manufacturing. 1993. US patent 5,258,915

5. Brandeau, ML.; Larson, RC. Extending and applying the Hypercube Queueing Model to deploy ambulances in Boston.. In: Ignall, E.; Swersey, AJ., editors. Management science and the delivery of urban service. North-Holland/Elsevier; New York: 1986.
6. Brandeau ML, Hopkins DSP, Melmon KW. An integrated budget model for medical school financial planning. *Oper Res*. 1987; 35(5):684–703.
7. Kahn JG, Brandeau ML, Dunn-Mortimer J. Operations research modeling and AIDS policy: from theory to practice. *Interfaces*. 1998; 28(3):3–22.
8. Hutton DW, So SK, Brandeau ML. Doing good with good OR: supporting cost-effective hepatitis B interventions. *Interfaces*. 2011; 41(3):289–300. [PubMed: 21760650]
9. Negoescu DM, Owens DK, Brandeau ML, Bendavid E. Balancing immunological benefits and cardiovascular risks of antiretroviral therapy: When is immediate treatment optimal? *Clin Inf Dis*. 2012; 55(10):1392–1399.
10. Zaric GS, Barnett PG, Brandeau ML. HIV transmission and the cost effectiveness of methadone maintenance. *Am J Public Health*. 2000; 90(7):1100–1111. [PubMed: 10897189]
11. Zaric GS, Brandeau ML, Barnett PG. Methadone maintenance and HIV prevention: a cost-effectiveness analysis. *Manage Sci*. 2000; 46(8):1013–1031.
12. Zaric GS, Brandeau ML. Optimal investment in a portfolio of HIV prevention programs. *Med Decis Making*. 2001; 21(5):391–408. [PubMed: 11575489]
13. Zaric GS, Brandeau ML. Resource allocation for epidemic control over short time horizons. *Math Biosci*. 2001; 171(1):33–58. [PubMed: 11325383]
14. Zaric GS, Brandeau ML. Dynamic resource allocation for epidemic control in multiple populations. *IMA J Math Appl Med Biol*. 2002; 19(4):235–255. [PubMed: 12828363]
15. Brandeau ML, Zaric GS, de Angelis V. Improved allocation of HIV prevention resources: using information about prevention program production functions. *Health Care Manage Sci*. 2005; 8(1): 19–28.
16. Enns EA, Brandeau ML, Igeme TK, Bendavid E. Assessing effectiveness and cost effectiveness of concurrency reduction for HIV prevention. *Int J STD AIDS*. 2011; 22(10):558–567. [PubMed: 21998175]
17. Enns EA, Brandeau ML. Inferring model parameters in network-based disease simulation. *Health Care Manage Sci*. 2011; 14(2):174–188.
18. Enns EA, Mounzer JJ, Brandeau ML. Optimal link removal for epidemic mitigation: a two-way partitioning approach. *Math Biosci*. 2012; 235(2):138–147. [PubMed: 22115862]
19. Hutton DW, So SK, Brandeau ML. Cost effectiveness of nationwide hepatitis B catch-up vaccination among children and adolescents in China. *Hepatology*. 2010; 51(2):405–414. [PubMed: 19839061]
20. Hutton DW, Brandeau ML. Too much of a good thing? When to stop catch-up vaccination. *Med Decis Making*. 2013; 33(7):920–936. [PubMed: 23858015]
21. Alistar, SS.; Owens, DK.; Brandeau, ML. Результативность и экономическая эффективность расширения программ снижения вреда и антиретровирусной терапии при < смешанной > эпидемии ВИЧ: анализ модели на примере Украины [Effectiveness and cost effectiveness of expanding harm reduction and antiretroviral therapy in a mixed HIV epidemic: a modeling analysis for Ukraine]. 2011. Available at http://www.plosmedicine.org/attachments/pmed.1000423_Russian.pdf
22. Long, EF.; Brandeau, ML.; Galvin, CM.; Vinichenko, T.; Tole, SP.; Schwartz, A.; Sanders, GD.; Owens, DK. Оценка эффективности и экономической эффективности стратегии расширенной антиретровирусной терапии в Санкт-Петербурге, Россия [Effectiveness and cost-effectiveness of strategies to expand antiretroviral therapy in St. Petersburg, Russia]. 2006. Available at <http://www.stanford.edu/dept/MSandE/cgibin/people/faculty/brandeau/brandeau.php>
23. Alistar, SS.; Brandeau, ML.; Beck, EJ. REACH (Resource Allocation for Control of HIV): a practical HIV resource allocation tool for decision makers.. In: Zaric, GS., editor. Operations research and health care policy. Springer; New York: 2013.
24. Alistar SS, Long EF, Brandeau ML, Beck EJ. HIV epidemic control: a model for optimal allocation of prevention and treatment resources. *Health Care Manage Sci*. 2014; 17(2):172–181.

25. Long EF, Mandalia R, Mandalia S, Alistar SS, Beck EJ, Brandeau ML. Expanded HIV testing in low-prevalence, high-income countries: a cost-effectiveness analysis for the United Kingdom. *PloS One*. 2014; 9(4):e95735. [PubMed: 24763373]
26. Brandeau, ML. OR in public health: a little help can go a long way.. In: Zaric, GS., editor. *Operations research and health care policy*. Springer; New York: 2013.
27. Brandeau, ML. Applying OR in health: a five-step path to sure-fire success. *OR/MS Tomorrow*. Dec. 2013 <https://www.informs.org/Pubs/OR-MS-Tomorrow/Features/Opinion-Applying-OR-in-Health-A-Five-Step-Path-to-Sure-Fire-Success>
28. Long EF, Brandeau ML, Galvin CM, Vinichenko T, Tole S, Schwartz A, Sanders GD, Owens DK. Effectiveness and cost-effectiveness of strategies to expand antiretroviral therapy in St. Petersburg, Russia. *AIDS*. 2006; 20(17):2207–2215. [PubMed: 17086061]
29. American College of Physicians. *Annals of Internal Medicine*. 2015. Available at <http://annals.org/public/about.aspx>
30. INFORMS Pubs Online. *Operations Research*. 2014. Available at <http://pubsonline.informs.org/journal/opre>