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ISPOR Report

# Application of Constrained Optimization Methods in Health Services Research: Report 2 of the ISPOR Optimization Methods Emerging Good Practices Task Force

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ABSTRACT

**Background:** Constrained optimization methods are already widely used in health care to solve problems that represent traditional applications of operations research methods, such as choosing the optimal location for new facilities or making the most efficient use of operating room capacity. **Objectives:** In this paper we illustrate the potential utility of these methods for finding optimal solutions to problems in health care delivery and policy. To do so, we selected three award-winning papers in health care delivery or policy development, reflecting a range of optimization algorithms. Two of the three papers are reviewed using the ISPOR Constrained Optimization Good Practice Checklist, adapted from the framework presented in the initial Optimization Task Force Report. The first case study illustrates application of linear programming to determine the optimal mix of screening and vaccination strategies for the prevention of cervical cancer. The second case illustrates application of the Markov Decision Process to find the optimal strategy for treating type 2 diabetes patients for hypercholesterolemia using statins. The third paper (described in Appendix 1) is used as an educational tool. The goal is to describe the characteristics of a radiation therapy optimization problem and then invite the reader to formulate the mathematical model for solving it. This example is particularly interesting because it lends itself to a range of possible models, including linear, nonlinear, and mixed-integer programming formulations. From the case studies presented, we hope the reader will develop an appreciation for the wide range of problem types that can be addressed with constrained optimization methods, as well as the variety of methods available. **Conclusions:** Constrained optimization methods are informative in providing insights to decision makers about optimal target solutions and the magnitude of the loss of benefit or increased costs associated with the ultimate clinical decision or policy choice. Failing to identify a mathematically superior or optimal solution represents a missed opportunity to improve economic efficiency in the delivery of care and clinical outcomes for patients. The ISPOR Optimization Methods Emerging Good Practices Task Force's first report provided an introduction to constrained optimization methods to solve important clinical and health policy problems. This report also outlined the relationship of constrained optimization methods relative to traditional health economic modeling, graphically illustrated a simple formulation, and identified some of the major variants of constrained optimization models, such as linear programming, dynamic programming, integer programming, and stochastic programming. The second report illustrates the application of constrained optimization methods in health care decision making using three case studies. The studies focus on determining optimal screening and vaccination strategies for cervical cancer, optimal statin start times for diabetes, and an educational case to invite the reader to formulate radiation therapy optimization problems. These illustrate a wide range of problem types that can be addressed with constrained optimization methods.

*Keywords:* Health care delivery, health services, health policy, medical decision making, operations research, constraints, optimal, optimization.



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**Background to the Task Force**

The proposal to initiate an ISPOR Good Practices for Outcomes Research Task Force was evaluated by the ISPOR Health Science Policy Council then recommended to the ISPOR Board of Directors for approval.

The task force was comprised of international subject matter experts representing a diverse range of stakeholder perspectives (academia, research organizations, government, regulatory agencies and commercial entities). The task force met approximately every five weeks by teleconference and in person at ISPOR conferences. All task force members reviewed many drafts of the report and provided frequent feedback in both oral and written comments.

To ensure that ISPOR Good Practices Task Force Reports are consensus reports, findings and recommendations are presented and discussed at ISPOR conferences. In addition, the first and final draft reports are circulated to the task force's review group. All reviewer comments are considered. Comments are addressed as appropriate in subsequent versions of the report. Most are substantive and constructive improving the report.

## Introduction

There are often many different options for improving health care policy or improving current practice in health care organizations. The optimal solution among those options, i.e., the solution that best achieves a defined goal, such as maximizing patient quality of life or minimizing patient waiting time for services, may not be readily apparent. Constrained optimization methods use mathematical techniques to help efficiently and systematically identify the best (optimal) of all possible solutions to a problem while considering the relevant constraints, such as budget limits or staffing capacity.

Of course, mathematically optimal solutions to all problems are not always feasible; other nonquantifiable criteria, such as political barriers that cannot be accounted for by defined constraints, have to be considered. However, optimization techniques can still be highly informative to decision makers in providing insights about optimal target solutions and the magnitude of the loss of benefit or increased costs associated with the ultimate policy choice. In health care, failing to identify a mathematically superior or optimal solution represents a missed opportunity to improve economic efficiency in the delivery of care and clinical outcomes for patients.

The ISPOR Optimization Methods Emerging Good Practices Task Force provided an introduction to constrained optimization methods to solve important health policy and clinical problems in its first report [1]. The previous report outlined the relationship of constrained optimization methods relative to traditional health economic modeling and simulation models and identified some of the major variants of constrained optimization models, such as linear programming, dynamic programming, integer programming, and stochastic programming.

In addition, the report graphically illustrated the formulation and solution of a straightforward integer program to maximize health benefit subject to a budget constraint. Further, it explained the steps in an optimization process: 1) structuring the problem; 2) formulating the mathematical model; 3) developing the model; 4) validating the model; 5) selecting the optimization method; 6) performing the optimization and conducting sensitivity analysis; 7) reporting results; and 8) using the results for decision making.

The principal objective of this second Optimization Task Force Report is to illustrate the application of constrained optimization methods in health care decision making. To identify relevant examples, we began by searching for award-winning health care papers from the Institute for Operations Research and Management Sciences (INFORMS) and the Association for European Operations Research Societies (EURO). From these papers, we then selected examples with models relevant for health economic policy or clinical decision making. Finally, we endeavored to select papers that collectively illustrated a variety of different constrained optimization methods. The three papers that received the most votes from the task force members were selected.

In this report, two of these three papers are compared with the steps in formulating, solving, validating, reporting, and using optimization models originally published as Table 3 in the first Optimization Emerging Good Practices Task Force Report. A slightly modified version of this previous table is presented as the ISPOR Constrained Optimization Good Practices Checklist (Table 1) in the current report. The first case study illustrates the application of linear programming to determine the optimal mix of screening and vaccination strategies for the prevention of cervical cancer [2].

**Table 1 – ISPOR Constrained Optimization Task Force Good Practices Checklist**

| Stage | Step | Description |
|---|---|---|
| Modeling | Problem structuring | Specify the objective(s) and constraints, identify decision variables and parameters, and list and appraise model assumptions |
| | Mathematical formulation | Present the objective function(s) and constraints in mathematical notation using decision variables and parameters |
| | Model development | Program the model in software to estimate the objective function(s) and constraints using decision variables and parameters as inputs |
| | Model validation | Ensure the model is appropriate for evaluating different combinations of decision variables and parameters |
| Optimization | Select optimization method | Choose an appropriate optimization method and algorithm on the basis of characteristics of the problem. |
| | Perform optimization/ sensitivity analysis | Use the optimization algorithm to search for the optimal solution and examine the performance of the optimal solution for reasonable sets of parameters |
| | Report results | Report the results of the optimal solution and sensitivity analyses |
| | Decision making | Interpret the optimal solution and use it for decision making |

Source: Crown et al. [1], Table 3, p. 315.