

Adventures in policy modeling! Operations research in the community and beyond[☆]

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Abstract

The literature describing operations research in the community is somewhat of a puzzle. On the one hand, several authors have denigrated the use of traditional operations approaches in addressing community problems, yet several studies document successful applications. Arguing that the operations research mindset is itself a great strength, we will review several examples where operations research methods have been employed creatively to the benefit of the community and beyond.

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The theme of the 2003 INFORMS meeting was “OR/MS in the Community.” Since that is the subject of this address as well, and the meeting program was on-line, I thought it would be interesting to see what was being presented around the theme of OR in the community at the world’s largest gathering of operations researchers. I began by searching for any talks with the word “community” in the title or abstract. I found an interesting presentation addressing the location of community corrections centers, and another project linking the University of Warwick to the community, but also learned that “multi-agent simulations are of great interest to the military modeling and

simulation community.” Undeterred, I keyed in the word “neighborhood.” I was rewarded with a presentation on neighborhood effects and drug-treatment outcomes, but also found a talk on “very large neighborhood search” (and learned that I should be more careful as such search might be tabu!).

I need not have searched the program to note that operations research applications in the community have been rare relative to other areas of endeavor. Nonetheless, there is a history of operations research and the community that is somewhat contentious and worth reviewing, while there are past and present examples that reveal the potential for applying OR in the community and beyond.

In a 1970 article in *Operations Research* [1], Russell Ackoff of the University of Pennsylvania reported a project whereby community planners from the disadvantaged Mantua neighborhood of Philadelphia turned to Penn faculty and students for assistance in various local development initiatives. These included

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developing an industrial complex housing several manufacturing firms, provision of employment services, establishment of a credit union, design of a community service station, and a community school. These are all good things, but as Ackoff stated, “Little of what we have done is OR, or even research in the conventional sense.” Indeed, Ackoff argued that operations researchers “. . . should want to help create a world in which the capabilities of OR are considerably extended but in which the need for OR is diminished.”

This does not sound like a recipe for growing a discipline. No, Ackoff gave up on operations research, as indicated in his 1979 tirade “The future of operational research is past” [2]. He was wrong, of course—the past 20+ years of achievements in operations research—in revenue management, transportation, logistics, supply chains, and computing, information systems and telecommunications, to name only a few—combined with so many advances in our theories and methodologies suggest that for OR, the future remains rather bright.

But I digress—even while Ackoff used his Mantua experience to formulate a more general complaint against OR, other operations researchers were using modeling methods to investigate a host of urban problems, notably the New York City Rand Institute, incorporated in mid-1969. The community problems addressed included housing for the poor, health, policing, corrections, economic development, and fire protection among others. The journal *Operations Research* published a special issue in 1972 devoted to urban problems. The articles provided progress reports from research conducted at NYC Rand as well as the Urban Institute in Washington, DC, and original models for districting/determining service area boundaries, allocating ambulances, and integrating schools.

1972 saw the publication of Dick Larson’s *Urban Police Patrol Analysis* [3], which received the Lanchester Prize for the best publication in operations research, while the results of the NYC Rand Fire project were published in book form in 1979 [4]. The fire project received several accolades, including the 1974 Lanchester Prize for Peter Kolesar’s and Warren Walker’s paper on the dynamic relocation of fire companies [5], and the 1976 NATO System Science Prize for research by Edward Ignall and numerous colleagues for improving the deployment of New York City’s Fire Companies [6]. Surely improving the performance of police and fire departments counts as an application of OR in the community.

Another creative example occurred in the mid-1970s. In re-thinking traditional approaches to policing, the

forward-thinking Police Foundation conducted a series of field experiments, with the Kansas City Preventive Patrol Experiment being the best known [7]. The basic idea was simple: five police beats received the normal level of preventive patrol (meaning one patrol car per beat), five beats received 2-to-3 times the level of routine patrol (so-called proactive beats), and five beats received no patrol (reactive beats, where patrol was confined to the beat’s boundary). The main findings from this experiment were null findings—that is, there were no significant differences across the different experimental conditions for major variables such as crimes, citizen’s perceptions of safety, and so forth.

Dick Larson was asked to review this study, and did so with the aid of simple OR models [8]. Unlike an agricultural field experiment, outcomes in different beats in this study are not independent. One way to see this is to note that the majority of incident data collected come from busy periods—and during busy periods, all the patrol cars are, well, busy—so the identification of patrol units with individual beats is lost. Dick showed that this and similar problems served to effectively destroy the experimental design.

Much of the work in urban OR conducted during the 1970s was summarized and extended in the book *Urban Operations Research* by Dick Larson and Amadeo Odoni [9], now available online at http://web.mit.edu/urban_or_book/www/ for anyone interested.

Not everyone was as impressed as I am when I look back at urban OR. In the same year that *Urban Operations Research* was published, Jonathan Rosenhead of the London School of Economics issued a blistering attack on the use of OR in urban planning [10]. He stated that “. . . the mainstream OR contribution does violence to the nature of the system under study.” In a manner similarly spirited to Ackoff’s earlier missive [2], Rosenhead advocated “anti-OR,” an approach that, among other things would “. . . be non-optimising, and multi-dimensional without resort to trade-offs.” In Rosenhead’s view, “. . . operations research, through its insistence on precise definition and quantification, limits itself to handling only ‘second rate’ problems” [10].

Similarly, in another 1981 article titled “OR in the Community,” Sue Jones and Colin Eden wrote of the “. . . inadequacy of traditional OR techniques for helping their clients” in the community [11]. With reference to a project meant to assist unemployed youth in their community, Jones and Eden complained that “During the total life of the project until now, we have used two decision trees, one multi-criteria analysis and critical path analysis from the body of textbook techniques” [11].

So what are we to take from such concerns? My own view is that these complaints are misplaced, in that they confuse “off the shelf” applications of OR methodologies with the creative applications of *operations research ideas* to community problems. Indeed, this critique dismisses what I believe is the great strength of our discipline, namely the operations research mindset.

And what is this mindset? The world is full of problems, but one has to work to structure them as such. Models are our greatest allies in this regard. Modeling need not be “off the shelf”—rather, modeling with OR techniques should be a celebration of creativity. The art of modeling serves to tease out the implications of various conjectures or hypotheses, and suggests what variables could be key, what data should be collected, and perhaps even how a solution can be implemented by focusing attention on decisions that must be made and their operational consequences.

From the same time period of the Rosenhead and Jones/Eden critique, here is a beautiful example of a creative model-based solution for a community problem courtesy of John Bartholdi, Loren Platzmann and colleagues [12]. Senior Citizens Inc. is a private non-profit serving the elderly in Atlanta, and one of their programs is Meals on Wheels. Each day, trucks delivering meals to elderly clients must be routed in “traveling salesman” fashion to contain delivery expenses. The locations of clients change each day as new elderly enter the program while others depart, thus whatever solution approach is used must be flexible and able to generate new routes on a daily basis.

Rather than solve for optimal traveling salesman tours, Bartholdi and colleagues developed a method based on the use of a space-filling curve. The particular construction used is illustrated in Fig. 1. This construction, known as a Sierpinski curve, is formed by iteratively dividing a square into quadrants, copying a scaled-down version of the basic construction into each quadrant, and connecting them up. This can be repeated to achieve whatever coverage density is desired. Any location in a geographical area translates to a position along the curve. Bartholdi and colleagues produced a booklet mapping geographical (x, y) coordinates to a position along the Sierpinski curve—no math needed! Drivers were simply instructed to visit clients in order of their position on the Sierpinski curve—no optimization needed either! The drivers selected the specific routes followed between clients. This same system was also used by the Atlanta American Red Cross to deliver blood to metro-area hospitals. What a beautiful example of the OR mindset.

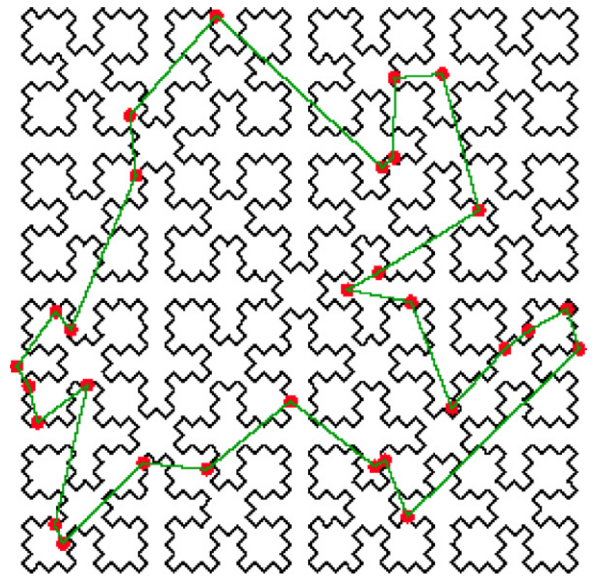


Fig. 1. A Sierpinski curve (http://www2.isye.gatech.edu/people/faculty/John_Bartholdi/mow/sfc-tour.gif).

Another concern raised by those identifying themselves as community OR practitioners relates to the role analysts play as potential advocates for one group or another. Parry and Mingers [13] finger operations research as playing a “. . . role in strengthening the grip of capitalism. . .” and to counteract “. . . the harmful effects of OR’s transition to management science. . .” these authors suggest that OR should be “. . . helping ‘grass-roots organizations’ with their own ‘counter-planning.’” Mar Molinero [14] also takes the position that there is an advocacy role for community OR, and indeed takes this position in an interesting article titled “Aldermoor School: The Operational Researcher on the Side of the Community” [15].

All of us are undoubtedly advocates for some group or cause, but in my view, who advocates what is more a matter of personal than professional values. Of course as individuals we should advocate for causes we find beneficial and just. But as operations researchers we need to be careful. Communities are not monolithic—and sometimes it might not be apparent that siding with one “community” might hurt another.

As an example, when I was a graduate student in MIT’s urban planning program, I was approached by an advocate for the residents of a large Boston public housing project to help with relocation planning (the advocate in question happened to be the boyfriend of one of my classmates). The apartment buildings in the project were being redeveloped, but in order for major construction to proceed in any building, the

residents of that building first had to be relocated to other quarters. Complicating matters, it wasn't immediately clear if temporary housing was available, as all temporary relocation was meant to occur on the project site. Thus, everyone involved was faced with a large game of musical chairs—to modernize one building required relocating the residents to other units, but these units themselves were either already developed from emptying earlier buildings in sequence, or would have to be emptied again at some future point if they had not yet been modernized. The advocate, project architects, and Boston Housing Authority planners had covered all of the walls in a small office with household/apartment occupancy data in an attempt to manually schedule all of the moves, and they were stuck: there were no feasible relocation moves that would satisfy all of the requirements for all of the households involved (e.g. size, features for the disabled, etc.). This was not a huge surprise to me. After all, there were 20 buildings, which means that there were $20! = 2.4 \times 10^{18}$ or about 2 billion billion sequences. The planners had gotten stuck while trying *one* sequence.

This was exciting for me—it was one of my first real-world OR modeling problems. I developed an integer program for minimizing the time required to redevelop the housing project, subject to constraints that insisted that all households were always housed in appropriately sized (or featured) units [16]. I found solutions that were not only feasible, but also shaved about 6 months off the time the architects had said would be needed. There is no question that the physical design and appearance of the redeveloped project is much, much nicer than the brick-block shoebox project that existed previously.

But there was a problem. The relocation program was a tremendous success for the occupants of the housing project. But what about those on the waiting list for public housing that had yet to receive a housing unit? To achieve the new design, the number of housing units in the project was reduced greatly. This lowered the unit turnover (even if on average household length of stay remained the same—it is more likely that residency times increased due to the improved surroundings which would lower unit turnover even more). And, since the redeveloped project was also so attractive, more people wanted to go there. All of these events led to a longer queue of households wanting in to the project.

It was easy to advocate for project residents—just go door to door and organize. Who advocated for those on the waiting list? Whose community matters? Was the impact on those waiting for public housing taken into account at all? At the time I was involved in this project, I felt it was a real success and that I had helped

improve matters for public housing residents. Looking back, however, I'm no longer certain whether this was a success.

In Britain, "community OR" has acquired a certain stature with the active support of the Operational Research Society. The Community Operational Research Unit of the ORS, initially established at Northern College in 1988 to "...provide community groups with more effective support in decision making" [14] moved to the Lincoln School of Management in 1998, where it remains active (<http://www.lincoln.ac.uk/home/research/groups/coru.htm>).

In 1994, the ORS published a volume titled *Community OR in Action* [17]. Chapters in this volume include titles such as "Landlords and tenants: a first brush with community housing," "Enabling the migrant resource centre to make their own decisions," and "Planning for disaster: developing a multi-agency post-disaster counselling service" among others. All of the chapters in this volume report perfectly reasonable community problems. It is interesting to me that these projects are not all that different from projects pursued at my home institution by Yale School of Management MBA students participating in the SOM Outreach program (<http://students.som.yale.edu/sigs/outreach/>). Recent projects include developing an entrepreneurial venture for a non-profit serving homeless and at-risk youth, a fundraising strategy for New Haven's Women and Families Center, and developing a business plan for a newspaper for the homeless.

I recognize an organizing principle for studies like these, but it is not community OR. Rather, the substantive study of community action problems is, at least in my experience, the province of community planning. For example, MIT's Department of Urban Studies and Planning, my former graduate program, features a field of specialization titled "Housing, Community and Economic Development." The program's web page describes itself as follows:

"HCED encompasses a commitment to social progress, a faculty working at the forefront of the field, and a student body committed to passionate involvement in complex urban issues. HCED focuses on the economic and social life of American cities and on initiatives to improve the lives of city residents, particularly those of low and moderate income living in urban neighborhoods." (<http://web.mit.edu/dusp/hced/about/hced/index.html>)

One would have a difficult time distinguishing the aspirations of MIT's program from community OR enthusiasts; at bottom both are trying to help disadvantaged groups in the community. The problem I and I suspect

many other operations researchers have is perhaps only semantic, but simply stated it is this: *operations research is not community planning*. However, there are many, many opportunities to apply the operations research mindset to problems in the community. Thus, while I certainly support operations researchers who choose to become involved with community problems, I feel it is a terrible mistake to discard the operations research mindset. I agree with those in community OR who argue that to work with the community, one needs to understand the community and its issues—both so that the problems can be understood in context, but also so that one can sound out and gain acceptance of one's own ideas. Indeed, handled properly, the impact of an operations research project in the community can extend far beyond its boundaries.

As a case in point, I refer to my own experience evaluating New Haven's needle exchange program [18]. In the late 1980s, 60% of New Haven's AIDS cases derived from drug injectors (as opposed to 30% nationwide). The simple idea behind needle exchange was to allow drug injectors to trade the used needles for clean ones to reduce needle sharing (and the HIV transmission that goes with it). The New Haven Mayor's Task Force on AIDS had lobbied for street outreach to drug injectors since 1987, while local AIDS activists had taken it upon themselves to illegally distribute and exchange needles on occasion in New Haven.

Between 1987 and 1990, intensive lobbying by local health officials and AIDS advocates successfully built a coalition in spite of opposition from some police officials, drug treatment providers, and community groups (including some clergy). A turning point came with the 1989 election of New Haven's first African-American mayor who appointed a new police chief; both became supporters of the needle exchange concept. Additional support was won from the New Haven Board of Health Commissioners, the Connecticut Association of Health Directors, the Connecticut Primary Care Association, the Connecticut Latino AIDS Advisory Council, and the Connecticut AIDS Action Council. All of this effort, with which I had nothing to do, culminated in the passage of legislation in May 1990 legalizing a demonstration needle exchange program in New Haven.

It was only after the legislation was passed that I was invited to design and conduct an evaluation of this program. There were several important constraints that had to be met: on the one hand, by the summer of 1991, it had to be determined via empirical study whether or not the program was succeeding in reducing HIV transmission; on the other, health department staff were adamant in insisting that program participants would *not*

be tested for HIV for fear of scaring them away. I was also told quite plainly that it would not be acceptable to have Yale students with telephone-book-sized surveys crawling all over the program. Given such constraints, how might one proceed?

The answer actually came from a mathematical model I had developed in 1989 [19]. This model viewed HIV transmission among drug injectors via needle sharing in a manner akin to the spread of malaria among people via mosquitos. The needles played the role of the mosquitoes in this model, thus the rate at which drug injectors would transmit HIV via needle sharing depends on the prevalence of HIV in the *needles* that are shared (while the prevalence of infection in the needles in turn depends upon the level of infection among drug injectors).

Viewing needle exchange through the lens provided by this model, it became clear that exchanging used needles for clean ones is equivalent to replacing mosquitoes in a malaria outbreak with newborns free of disease. This immediately suggested what came to be known as a circulation theory of needle exchange [20,21]: exchanging needles in one-for-one fashion does not change the number of needles in circulation, but it does increase the *turnaround* of such needles. This increase in the turnaround forces a reduction in the duration of time needles spend circulating among drug injectors. Reducing a needle's circulation time also reduces the number of different times that needle can be shared, which lessens the chance of that needle becoming infected. Simply stated, needle exchange forces needles to share fewer people! Finally, if fewer needles become infected, fewer people will as well.

To test this theory required the development of a novel syringe tracking and testing system that would record the use of the program by clients, but also the detailed travels and infection status of individual needles [18]. Over time and as expected based on the volume of needles exchanged, the level of infection measured in the needles fell. Based on these data, the models estimated conservatively that the rate of new HIV infections among program participants declined by 33%.

Not only were these results found sufficiently convincing by city officials and state legislators to continue the program (and indeed to expand needle exchange in Connecticut), many other jurisdictions in both the United States and abroad were able to instigate their own programs based on this work [18,22,23]. In addition to the specific evaluation results, several important side benefits emerged, including a new estimate for the probability of transmitting HIV via a single injection with a contaminated syringe [24], a new method for

estimating HIV incidence among drug injectors [25], a new method to estimate the number of drug injectors in a metropolitan area [26], and a model for the economic analysis of needle exchange, including the identification of conditions under which it would or would not be justifiable (on cost–benefit grounds) to establish such a program [27].

I would argue that this experience contained all of the elements that community OR enthusiasts contend are so important (and certainly were in this case). Indeed, given that the program evaluation was embedded into program operations, the protocol was worked out jointly in regular meetings with a diverse group including city and state government representatives, community agency heads, AIDS activists and drug treatment providers, health department officials and staff, New Haven’s Chief of Police, the program’s outreach workers, and former drug injectors.

Yet, I would also argue that the mathematical OR modeling was tremendously important to the overall success of this project. Without the OR component, in fact, it is doubtful that the needle exchange program would have lasted beyond its first year, as it would have been very difficult to argue that the program was achieving what it was intended to achieve. Instead, nearly 15 years on, the needle exchange continues to operate as a health department program in New Haven.

While the needle exchange experience will forever remain strong as an example of operations research (including mathematical OR modeling) in the community, it is by no means the only example. Many other researchers have devoted substantial effort and time to research policy problems whose impact is felt in the community and beyond. I will not attempt an exhaustive survey, but simply cite a few such researchers to give a sense of some of the activity in what I refer to as “policy modeling.”

Operations research and drug policy is a good example. Pioneered by Jonathan Caulkins of Carnegie Mellon’s Heinz School of Public Policy and Management, Jon’s work in this area began while he was a doctoral student at MIT’s Operations Research Center where his thesis research included street-level observation of drug markets in Hartford, Connecticut and the response of these markets to geographically targeted law enforcement efforts [28]. Since then, he has emerged not only as a leading operations researcher studying drug policy, but also as a leading drug policy scholar with analyses addressing alternative drug-control policies via OR modeling. Some of the work that Jon and his colleagues have completed includes consideration of whether drug enforcement (“supply side”) or drug

treatment (“demand side”) policies are more likely to reduce cocaine consumption (for the curious, treatment wins over a wide range of parameters, but see [29] for the details), whether “zero tolerance” sentencing policies (where those guilty of drug possession face the same sentences without regard to the quantity of drugs involved) are effective in reducing consumption (they’re not [30]), and how the portfolio of drug prevention and treatment programs should be balanced over time [31]. There is no question that illicit drug use impacts many communities, and Jon’s research, while not rooted in any single community, has fed into the larger policy process in the United States in a manner that impacts all communities. Jon’s work has been cited in administration requests for incremental funding and agency investments in drug prevention programs. Indeed, via his reports and briefings for the Office of National Drug Control Policy, the Congress, state legislatures, mayors and governors, Jon’s work has affected the way policy makers *think* about drug control, moving the emphasis from one based purely on enforcement to consideration of how drug markets operate, and the drug market consequences of alternative control policies for illicit drug consumption.

Al Blumstein’s research on homicide and gun availability is another good example [32–34]. Again, though not rooted in any particular community, understanding the forces underlying trends in violence is important to separate changes in crime that might be policy related from changes due to demographics or other secular trends. And again, the real impact of this sort of policy modeling research is on the way people *think* about these problems.

As a third example, I return to HIV prevention and the question of how best to stop the spread of HIV. In the United States, federal funds for HIV prevention are distributed from the Centers for Disease Control to individual state health departments who then contract with local non-profit organizations to deliver specific programs and services. Informing this budget-allocation activity is a formal *community planning process* whereby in each of the states (and largest metropolitan areas hardest hit by HIV/AIDS), *community planning groups* consisting of a mix of activists, service providers, government officials and researchers recommend priorities for funding (though the actual funding decisions remain in the hands of the health departments). In reviewing the actual processes used by community planning groups to arrive at their recommended priorities [35], I became convinced that in attempting to guarantee that funds be distributed in a manner that was perceived by funding recipients and community advocates as fair and

equitable, the overriding goal of HIV prevention—to prevent as many infections as possible—had been lost. This led me to propose an approach to community planning that recognized explicitly the underlying optimization problem—which programs should be funded (and in what amounts) to prevent as many HIV infections as possible? I described the method in a chapter for a handbook on evaluating HIV prevention programs [36], and set about trying to convince Connecticut’s community planning group to experiment with the method.

The approach proposed forced users to estimate (or at least “agree to believe”) the relative share of new infections that would occur among different risk groups, and the proportion of these infections that could be averted as a function of resources allocated to programs serving these groups. With these (subjective) inputs, my spreadsheet solved (via dynamic programming) the underlying nonlinear knapsack problem to recommend “optimal” budget allocations that, consistent with the community planning group’s family of assumptions, would prevent as many new infections as possible.

The Connecticut planning group met several times to consider and experiment with this tool, but ultimately they could not come to grips with the subjective estimation demands of the model, nor the possibility that to prevent as many infections as possible, perhaps some programs and services should go unfunded—that is, that there could be losers as well as winners in allocating HIV prevention resources.

Undaunted, I presented the methodology at a national meeting of HIV prevention community planning groups, and gave the spreadsheet away free of charge. While I received (and continue to receive) requests for the associated materials from community planning groups and health departments, to my knowledge no individual community planning group actually used it to reach their recommendations for how to allocate funds.

However, the modeling approach received a second lease on life when in 1999, the Centers for Disease Control requested that the Institute of Medicine of the National Academies of Science conduct a comprehensive review of HIV prevention efforts in the United States with an eye towards recommending a new strategy for domestic HIV prevention. As luck would have it, I was asked to join this new Committee on HIV Prevention Strategies in the United States. It quickly became apparent that although the issues were now at the national rather than the community level, the key question remained the same: given the resources available for HIV prevention, what is the best way to allocate them?

The committee (which again consisted of a diverse group of researchers, and health and community

officials and administrators) quickly came around to an overarching recommendation. To quote from our report, “As a starting point, the nation should adopt an explicit prevention goal: **to avert as many new HIV infections as possible with the resources available for HIV prevention.**” [37, p. 4, *emphasis in the original*] The most important contribution of the model, now recast at the national level, was not the specific numerical results it produced, but rather the *framework* it provided for discussing numerous policy issues, such as:

- the value of targeting resources (by geography, risk group, etc.) to those where HIV prevention would yield the greatest incremental number of infections prevented,
- the value of obtaining additional resources (by shadow pricing the budget in terms of foregone HIV infections prevented),
- the tradeoff between equity and efficiency in HIV prevention (by viewing equity as funding constraints imposed on an otherwise efficiency-driven proposal, and shadow pricing the equity constraints in terms of foregone HIV infections prevented [38]),
- the real cost of federal funding prohibitions on various prevention programs (such as sex education in schools beyond abstinence-only, needle exchange, etc.), again by treating such prohibitions as constraints on the allocation process and shadow pricing these constraints in terms of foregone HIV infections prevented,
- the need for better HIV surveillance (since to estimate the number of new infections that can be prevented, one first needs to know how many new infections there are to prevent!).

The story doesn’t end here. I was invited to present these resource allocation methods to the World Bank, which faces the same problem in countries around the globe. World Bank health economists took it upon themselves to tailor the model for use in allocating resources in Honduras [39], and pleased with those results (and others) are now using the approach in China and considering it for use in an additional five South Asian countries (http://www.iaen.org/files.cgi/13258_Regional_HIV_Initiative_Concept_Note.pdf). Thus, what some might dismiss as a failure at the initial community level has turned into a valuable tool for allocating HIV prevention resources in many countries around the globe.

As a final example, the terror attacks of September 11, 2001 forced the recognition and reconsideration

Table 1
Application areas for community OR

Problem terrain
Affordable housing
Crime and violence
Disaster planning and recovery (e.g. terrorism)
Discrimination and hate
Drugs
Education
Environment
Hunger
Jobs and economic development
Poverty
Public health
Public services (e.g. police, fire, transportation)

of the damage terrorists are capable of unleashing on communities worldwide. While many critics are more captivated by policy debates regarding foreign policy and its relation to terror threats, how to prepare for additional terror attacks (and the horrible creativity such attacks could manifest) remains a pressing and real concern. Operations research can build on its history of successful applications in emergency response systems and public health to contribute usefully to such efforts. Examples include developing robust responses to potential bioterror attacks involving smallpox or anthrax [40,41], studies to see which tactical measures are more or less likely to stimulate/retard suicide bombing attacks [42], or analysis of measures meant to prevent terrorists from entering a country [43]. I'm not suggesting that these topics should be considered "community OR" per se, but the importance of getting these problems right seems clear.

To conclude, there are clearly many, many areas where OR could be applied in the community. Some of these have already received a fair amount of attention, notably urban services, crime, and more recently drugs, violence and public health. But other areas are wide open and waiting for us to address them. The listing in Table 1, while not exhaustive, suggests the range of topics to which operations research—including mathematical OR modeling—can be applied in the community. Quibbling over which approaches can and cannot be employed pales in my view to actually setting out to do the work. As suggested in Table 1, there is much work that remains to be done to the benefit of communities—indeed to the benefit of us all.

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