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Decision Science for Community Development and Social Change

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DECISION SCIENCE FOR COMMUNITY DEVELOPMENT AND SOCIAL CHANGE

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MY STORY

Who am I?

- Second-generation college graduate
- Born in Midwest; culturally identifies with Northeast
- BS, Morehouse College (math and French); MS, Georgia Tech (electrical engineering); MS, University of California, Berkeley (operations research); PhD Northwestern University (operations research)
- Professor and chair, Department of Public Policy and Public Affairs, University of Massachusetts Boston (<u>https://mccormack.umb.edu/academics/pppa</u>)
- Founder and chair, INFORMS committee on Diversity, Equity and Inclusion (<u>https://connect.informs.org/diversity/home</u>)
- Co-founder and member, INFORMS Pro Bono Analytics (<u>https://connect.informs.org/probonoanalytics/home</u>)
- Planning team co-chair, Boston node, Urban Research-Based Action Network (<u>https://urbanresearchnetwork.org/nodes/local-nodes/boston/</u>)
- President, Boston chapter, National Forum for Black Public Administrators (<u>http://www.nfbpaboston.org/</u>)

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How did I get here?

Before college:

- My mother started her career at the Department of Housing and Urban Development. I guess I went into the family business.
- People say they expected me to be a journalist. I do love public affairs.
- I went to a selective high school in New York City. I embrace and reject many values associated with elite institutions.

In college:

- I chose Morehouse College over the Ivies. Morehouse's tradition of public service and social justice has marked me for life.
- I heard about operations research at Morehouse. I've always thought that OR could be the perfect profession for those who want to use numbers and models to make a difference in the world.
- I did a dual-degree program at Georgia Tech. I never thought of myself as a conventional engineer.
- I studied and traveled in West Africa after graduation as a Thomas J. Watson fellow.



How did I get here?

At Carnegie Mellon University:

- CMU attracted me because it has one of the few policy schools with a presence in operations research and information technology.
- I continued work in decision models for assisted and affordable housing.
- I decided I really liked supervising graduate student project courses and did a community plan for a local community development corporation.
- My 2007 paper on community-based operations research represented a career inflection point.

At UMass Boston:

- I felt that UMB's urban mission, emphasizing community engagement and social justice, was a great fit for me.
- The 2007 housing crisis prompted me to focus on foreclosure response and distressed and shrinking communities
- My current work embraces mixed methods, multi-disciplinarity, diversity, equity and inclusion and community capacity building.
- I'm department chair because I like people, problem-solving and institution-building.



Where I teach

John W. McCormack Graduate School of Policy and Global Studies

- Department of Public Policy and Public Affairs
- Department of Gerontology
- Department of Conflict Resolution, Human Security and Global Governance

Public Policy and Public Affairs degree programs

- Certificate program in Gender, Leadership and Public Policy
- Master in Public Administration
- Public Policy PhD

Also...

- Masters program in Urban Planning and Community Development
- Masters program in Transnational, Cultural and Community Studies



My current research questions

- What has the decision sciences profession done to address important social problems in which diversity, equity and inclusion play a strong role?
- What can the decision science profession do to meet diversity, equity and inclusion goals for the primary professional society; the larger population of students, practitioners and scholars, and the STEM profession generally?
- Big data and smart cities are presumed to enable urban areas to provide better quality of life and support better use of resources. Under what circumstances is this true for cities, regions and communities facing long-term declines in population and economic activity?
- In what ways can decision sciences enable communities facing shrinkage and decline to develop strategies to live better without necessarily pursuing a growth agenda?
- How can community data analytics and community-engaged operations research support under-served, marginalized and shrinking communities and the organizations that serve and represent them?



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INTRODUCTION TO OPERATIONS RESEARCH

What is Operations Research?

- A scientific approach to decision making
- A discipline concerned with optimal design, operation and management of systems under resource limitations
- Also known as: management science, decision models, decision science, industrial engineering, analytics
- Methods and insights drawn from: mathematics; economics and other social sciences; urban and regional planning; sciences and engineering
- Applications to: public policy and public management; health care; military; business management, finance, operations and strategy



How is Operations Research related to other disciplines?

	Descriptive/ Ex Explanatory Exp	ploratory/ Prescriptive perimental
Positive	Observation-based social Anthropology, Sociology	sciences: /, others
	Model	-based social sciences and applied engineering: Behavioral decision making, Risk analysis
Normative	Model-based social sciences: Management, Information techr	Economics, nology, others
		Model-based management and information sciences: Operations research, Analytics, GIS/spatial analysis, Information technology
	1	
	Traditional focus of public policy-related inquiry	Focus of other disciplines w applications to public polic



Operations Research as an analytic method

- Study a process or phenomenon to determine what actually happens and what ought to happen
- Develop a representation incorporating all actors
- Measure actual characteristics of process
- Determine the effect of changes in model characteristics on process output (prediction)
- If possible, choose a most-desired course of action (prescription)
- Validate the model using actual data
- Implement the model through changes in organization practices





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* Gartner Research - Modified

EXAMPLES OF OPERATIONS RESEARCH MODELS

The facility location problem

An organization wants to design a network of facilities in order to serve customers:

- Facility locations
 - *P* identical potential facility locations
 - Each location serves customers who travel to it
 - Maximum of $p \le P$ facilities to be sited
- Customers:
 - M customer locations
 - Demand at each customer location is known, equal to population
 - Customer can be served by a facility if the distance between it and the facility is ≤ S

What is the minimum cost set of facilities that can serve all demands? What configuration of *p* facilities will serve demands most efficiently?



How can we represent this system graphically?



How can we represent this system mathematically?

Set Covering Problem $a_{ij} = \begin{cases} 1, if candidate site j can \\ cover demands at node i \\ 0, if not \end{cases}$ $f_j = cost of locating a facility at \\ candidate site j \\ X_j = \begin{cases} 1, if we locate at candidate site j \\ 0, if not \end{cases}$

Minimize $\sum_{j} f_j X_j$

Subject to: $\sum_{j} a_{ij} X_j \ge 1 \quad \forall i$ $X_j = 0, 1 \qquad \forall j$

MCCORMACK GRADUATE SCHOOL OF POLICY AND GLOBAL STUDIES UNIVERSITY OF MASSACHUSETTS BOSTON $\begin{array}{l} \textbf{P-Median Problem} \\ X_{j} = \begin{cases} 1, if we \ locate \ at \ candidate \ site \ j \\ 0, if \ not \end{cases} \\ Y_{ij} = \begin{cases} 1, if \ demands \ at \ node \ i \ are \ served \ by \\ a \ facility \ at \ node \ j \\ 0, if \ not \end{cases} \end{array}$

Minimize $\sum_i \sum_j a_i d_{ij} Y_{ij}$

Subject to:

$$\begin{split} \sum_{j} Y_{ij} &= 1 & \forall i \\ \sum_{j} X_{j} &= p \\ Y_{ij} - X_{j} &\leq 0 & \forall i, j \\ X_{j} &= 0, 1 & \forall j \\ Y_{ij} &= 0, 1 & \forall i, j \end{split}$$

Why is this problem interesting?

- Analytic insights
 - Problems can be solved using mathematical optimization, heuristics or simulation
- Operations insights
 - Descriptive: What is the set of customers that can be served by each facility?
 - Prescriptive:
 - What is the maximum demand that can be served by p = 1, 2, ..., P facilities?
 - How do demands served optimally vary according to p?
 - How do sited facilities vary according to f_i ? To coverage radii a_{ij} ?
- Management and policy insights
 - Is minimizing total cost, or demand-weighted distance, the only salient objective for the respective problems?
 - How is locating a library different from locating a grocery store?
 - Is distance a good measure of accessibility?
 - Is number of customers a good measure of demand?



The queueing problem

A bank and the customers it serves are characterized in the following way:

- Servers:
 - *M* identical tellers
 - Each teller services an average of μ customers per hour
 - Arranged in parallel
- Customers:
 - Each waits in a single line to be seen by a teller
 - Arrive at a rate of λ persons per hour
- Service discipline:
 - First-come, first-served

What quality of service can be provided to customers?



How can we represent this system graphically?

The Bank Branch





How can we represent this system mathematically?

Let us assume that we want to solve the queueing problem for a single server.

Let t_i = time that *i*th customer arrives.

Define $T_i = t_{i+1} - t_i = i$ th interarrival time.

Assume that T_i 's are independent, continuous random variables described by a random variable **A**

If λ is the average arrival rate, then we can show that the *average* interarrival time = 1/ λ , and the *variance* of the interarrival time is 1/ λ^2 If interarrival times are *exponentially-distributed* with parameter λ , then the number of arrivals in time t follows a *Poisson distribution* with parameter λt .

Then we can show:

- The probability of *n* arrivals in time period $t = P(N_t = n) = \frac{e^{-\lambda t}(\lambda t)^n}{n!}$
- The expected number of arrivals in any time interval of length $t = \lambda t$.



Why is this problem interesting?

- Analytic insights
 - Exact solutions available for particular server configurations, service disciplines and service time and interarrival time distributions.
 - Otherwise, heuristics and simulations often used to solve problems
- Operations insights
 - Descriptive
 - What is the average time a customer waits in line?
 - What is the total average service time?
 - Prescriptive
 - What configuration of waiting lines and tellers; and arrival and service rates can minimize waiting time?
 - How can we incorporate human behavior such as cutting, balking (refusing to join the queue) and reneging (leaving the queue after entering)?
- Management and policy insights
 - How is a human services organization, or a parking lot, or a bikesharing stand different from a bank branch?
 - Are there public planning problems that combine aspects of facility location and queueing?

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PUBLIC-SECTOR OR

What is special about public-sector decisionmaking?

- Political concerns are fundamental
- Outcomes are difficult to measure
- Market imperfections
- Ill-defined, 'messy' problems
- Bureaucracies differ from "line" organizations
- Elected officials have severe time constraints
- Balance efficiency, effectiveness and equity
- How do we know if a correct decision has been made?



Many public problems require a different focus than private-sector problems

- Key attributes:
 - Underrepresented/isolated/vulnerable populations
 - Localized as well as national-level responses
 - Recipients of social services and interventions as well as systems or physical infrastructure
 - Understanding of political economy and cultural and social context
- Traditional OR approach limited by technocratic, topdown, consultancy model

A new approach should place value on needs of community members to identify, structure, model and solve problems and implement solutions



Examples of public-sector OR applications

Application Area	Operational or Strategic?	Well-Defined or III-Defined?
School desegregation plans		
Garbage and snow removal vehicle routing		
Energy policy analysis		
Blood bank operations		
Post-disaster recovery		
Solid waste management		
Police patrol and dispatching		
HIV/AIDS policy design		
Urban planning/ redevelopment/ reconstruction		



Many important public problems are not wellunderstood

- What measures of 'resiliency' are important to the wellbeing of vulnerable communities?
- How can low-income communities choose redevelopment strategies that balance opportunity and protection?
- What mix of energy development options are affordable to a wide range of populations?
- How can a school district design a lottery system for public schools that balances desires for local access and academic excellence?

Problems that are hard to define (see e.g. Rosenhead and Mingers 2001), that require a deep understanding of local needs, and whose solutions depend on active community participation can be addressed using *community operational research*



Characteristics of Community Operational Research

Defining feature: *meaningful engagement of communities*

Key principles:

- Requires *intervention*, i.e. "purposeful action by an agent to create change" (Midgley 2000)
- Local engagement and impact
- Concern for disadvantaged, underrepresented and underserved populations
- Focuses on problem-solving processes as well as outcomes
- Embodies a critical approach and a concern for ethics
- Prefer qualitative and mixed-methods approaches to problem-solving
- Prefer interventions that create local empowerment and social change

COR can productively address many problems of social concern, including those outside areas traditionally associated with OR



Designing and implementing effective COR responses is difficult...

Challenges:

- Ordinary citizens may lack analytic and problem-solving skills
- Requires broad and ongoing participation by multiple stakeholders
- Knowledge produced by COR supports learning for decision-making rather than model-generated prescriptions
- Lacks high-profile solutions and innovations associated with metaphors of logistics and business operations

Opportunities:

- Increased interest in OR for public good
- Distrust of government institutions provides space to reconcile technology and management with real-world understandings and problems
- Identify specific application areas where COR may generate insights, strategies and operational recommendations



Community engagement principles

What is the community?

- Residents in a geographical locale
- Members of a self-help group
- Population with particular needs or requirements
- On-line and/or in-person
- What is *engagement*?
 - Includes, but is not limited to, consultation
 - Supports input by community into issue framing, problem formulation and solution, policy implementation
 - Prevent co-potation, manipulation, exclusion, tokenism
- What communities are of special interest?
 - Disadvantaged, under-served, excluded, under-resourced, marginalized persons, groups or neighborhoods
 - Dimensions of identity that are salient to problem at hand



COR-inspired alternative modeling approaches and impact measures

- Multiple levels:
 - First-level: Who is not at the table? What are the social concerns not obvious in the model?
 - Second-level: Who builds, vets and implements the model?
 - Third-level: What analytic and methodological framework should matter most for a particular case study?
- Multiple impacts:
 - Deep understanding of theory, context and stakeholders can generate long-lasting and sustainable solutions
 - The third-level approach can go beyond organizational change to support social justice and social change



Community-based operations research enlarges traditional notions of decision modeling...





Source: Johnson (2012)

...and accommodates elements of participatory action research and COR





Source: Johnson (2012)

APPLICATIONS OF COMMUNITY-ENGAGED OR: POLICY AND PLANNING FOR FORECLOSURE RESPONSE

Policy motivation: Housing foreclosures

- Aggregate effects:
 - Over 4 million homes lost to foreclosure during Great Recession of 2007 -2012
 - 30% decline in house prices
 - \$7 trillion in home equity lost
- Socio-geographic concentrations:
 - High-priced areas that overbuilt
 - Economically struggling cities with high rates of subprime lending
 - Lower-income and minority households
- Social and economic consequences:
 - Residential stability
 - Personal well-being
 - Spill-over effects



Analytic response

- Focus on community-level foreclosure response: acquisition, management, rehabilitation, disposition of distressed properties
- Value-focused thinking: clarify objectives, attributes, decision opportunities
- Analytics: quantify impacts of foreclosure responses
- Stochastic dynamic programming: design bidding strategies and manage housing portfolios
- Multiobjective math optimization: identify acquisition and redevelopment opportunities



Key findings: values analysis

Use value-focused thinking to identify decision strategies for diverse community partners





Source: Johnson et al. (2016)

Key findings: decision modeling

Use estimates of foreclosure response impacts to solve multiobjective optimization problem problem for property acquisition





Was this a successful application?

- Our goal was to use qualitative, community-engaged methods to identify solution opportunities, then solve empirical problems
- In practice, VFT applications yielded great insight, but quantitative analysis proceeded in parallel with qualitative analysis
- Funding limitations prevented solution implementation and community outcomes evaluation



APPLICATIONS OF COMMUNITY-ENGAGED OR: SHRINKING CITIES AND VACANT LAND MANAGEMENT

Policy motivation: Vacant land and abandoned properties

- Symptoms:
 - 30 cities with 500,000 or more residents have lost 8.61% of their populations on average
 - Number of vacant housing units has increased by 44%
 - Eight cities facing population declines have incurred \$23 billion in debt before declaring bankruptcy
- Causes:
 - Urban deindustrialization
 - Federal policy supporting out-migration to suburbs
 - Foreclosed housing crisis and the Great Recession
- Traditional remedies:
 - · Investments in housing, employment and physical infrastructure



Sources: Popper and Popper 2002, Hollander et al. 2009

Analytic response

- Classify vacant or abandoned parcels in blighted neighborhoods for multiple non-traditional uses
- Apply multi-objective optimization to select aggregations of parcels for new uses
- Evaluate actual decisions of planners for test data to infer values structures



Key findings: prescriptive modeling

Multi-objective optimization: objective space vs. decision space





Source: Johnson, Hollander and Davenport Whiteman (2015)

Key findings: values analysis

	Theme	Why Important	Criteria	Metrics
	Strategic demolition and rehabilitation	Support existing homeowners and bolster redevelopment efforts	Blight elimination	Crime hotspots
, .				Code enforcement problem areas
Values			Support existing redevelopment	Proximity to areas with current redevelopment projects
structures		Improve quality of life for Baltimore residents	Whole block outcomes	Blocks with high vacancy concentration
inferred from			Neighborhood stability	Proximity to areas with high owner-occupancy
planner		Stabilize neighborhoods	Targeted investment	Proximity to areas with current redevelopment projects
				Proximity to areas with high owner occupancy
decisions using				Areas with high vacancy concentration
sample				Housing market typology (distressed categories)
neighborhood	Budgetary constraints and challenges	Apply limited funding in an equitable and maximally effective way	Equitable distribution of funds	
			Targeted investment	
data			Cost	Minimal acquisition
				Minimal relocation
				Minimal need for structural supports
				Request from the community/community organizers/city councilmen, etc.
				Historic value/preservation



Source: Johnson, Hollander and Davenport Whiteman (2015)

Was this a successful application?

- Decision modeling approach meets needs of planners
- Researchers were prevented by partners from engaging with community stakeholders
- Social justice-focused 'smart shrinkage' is difficult to practice; brings baggage of previous discredited efforts such as urban renewal
- Current book project seeks to enlarge concept of data, technology and analytics to enable residents of distressed and declining communities to lead in local redevelopment



Conclusion and next steps

- Community-engaged OR is an emerging sub-discipline with ties to diverse research traditions and demonstrated organizational and social impacts
- My exploration of this area is based on my formative experiences at Morehouse College and my adoption of its core values of service, engagement and social impact
- Community OR and community-based OR can bridge gap between the success of 'hard-OR' in addressing welldefined and analytically complex quantitative problems, and the challenges of 'wicked' problems that require more inductive, collaborative and mixed-methods approaches
- Promising community-engaged OR applications arise from issues in diversity, equity and inclusion in the profession, the discipline and society at large.



Thank you!



Sources: Author (first row); Boston Main Streets Foundation, 2015 (second row)



Resources

- Institute for Operations Research and the Management Sciences (INFORMS) OR and Analytics home page: <u>https://www.informs.org/Explore/Operations-Research-Analytics</u>
- INFORMS Pro Bono Analytics home page:

http://connect.informs.org/probonoanalytics/home.

• INFORMS Diversity, Equity and Inclusion home page:

https://connect.informs.org/diversity/home

 European Journal of Operational Research Special Issue on Community Operational Research:

https://umb.libguides.com/communityoperationalresearch



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