Notes from meeting with Shahriari (9/12/17)
How do you come up with an objective function for CBOR problems? (It's harder when you have competing objectives)
How do you incorporate other disciplines into CBOR? How do you combine the qualitative with the quantitative?
Not so much interested in theory of CBOR as opposed to specific examples of it in action
For next time: overview of whole book
For friday info thing just try to write what thesis is about, guiding questions, etc

Notes from meeting with Shahriari (9/26/17)
Might be interesting to look at supply chain - nonprofit comparison chapter, especially with respect to the differences between the two.
Ideally, pick one area and bore down on it and understand it. (parks? illinois schools?)
Notes from meeting with Shahriari (10/3/17)
Course for future: become expert on multiobjective discrete facility location problems For next time: GET TO THE MODEL!
Notes from meeting with Shahriari (10/10/17)
Need to come up with a toy problem!
Thesis Outline
Ch 1: intro
Ch 2: toy problem
Ch 3: actual model
Ch 4: Multiobjective facility location
Ch 5: discrete facility location problems

OR Thesis Notes because I forgot Notebook
OR BOOK OVERVIEW FOR 19-8

- Divided into 4 parts
- Part 1 "Models and Analytic Methods"
  - Ch 1 and 2 seem to be intros
  - Ch3 is called "Operations Management in Community-Based Nonprofit Organizations"
  - Ch4 is called "Modeling Equity for Allocating Public Resources"
- Part 2 "Facility Location and Spatial Analysis"
  - I don't understand most of these titles
  - Ch5: Spatial Optimization and Geographic Uncertainty: Implications for Sex Offender Management Strategies
    THOUGHT: I imagine this means handling where to "place" sex offenders (so as to reduce exposure to children???? wording could be better on this sentence tbh)
  - Ch6: Locating Neighborhood Parks with a Lexicographic Multiobjective Optimization Method
    THOUGHT: what?!??! need to read intro to this or something
  - Ch7: Using GIS-Based Models to protect children from lead exposure
    THOUGHTS: how? what could it mean
- Part 3: Minorities and Disadvantaged Groups
  THOUGHTS: this seems like it could be the most problematic lol
  - Ch8: A Model for Hair Care Flow in Salons in the Black Community
  - Ch9: Street Gangs: A modeling approach to evaluating "at-risk" youth and communities

- Ch10: Fair fare policies: pricing policies that benefit transit-dependent riders

- Part 4: Service Delivery
  THOUGHTS: sounds like a lot of overlap with "regular" OR
  - Ch11: decision making for emergency medical services
  - Ch12: capacity planning for publicly funded community based long-term care services
  - Ch13: a DEA application measuring educational costs and efficiency of illinois elementary schools

1 Introduction

1.1 Motivation for This Book

- A brief history of OR/MS is provided in Pollock and Maltz (1994)
- Majority of OR/MS problems solved by students when introduced to discipline are drawn from the private sector: production planning, logistics and distribution of goods, call center management, portfolio optimization, and other things. Barely any are problems that have social impacts, which is problematic considering nonprofits account for $1.6 trillion in revenue and $3.4 trillion in assets.
  - THOUGHT: Why is relative importance still measured in terms of money though??
- Much of our lives defined by things provided by not-for-profit means (education, public safety, human/social services, community and economic development, environmental conservation and preservation).
- Importance of decentralized government resources: we want emergency medical services to respond quickly to calls from our neighborhood first, we complain about waste in nearby areas as opposed to areas we do not often visit, care about the quality of our local schools first and foremost, etc.
  - THOUGHT: Mentions that social movements around the world have focus on local organizing, so how can local organizing benefit from OR???
- We care more about the impact of policies on groups of people who share our values, upbringing/racial/ethnic background, or who live near us, as opposed to those who are different — thus we need OR/MS applications that respond to public needs of a local nature (p4).
  - BUT can't all be local because need to account for populations that have differing levels of prosperity or political and social influence (see: rich vs poor)
- "We refer to OR/MS applications that address provision of goods and services, or prescribe social policy actions, for which stakeholders are defined, in a spatial or social sense, as localized, or who are considered disadvantaged or underserved, or for which issues of equity or social influence are important considerations, as examples of community-based operations research (CBOR)" (4-5)
  - THOUGHT: Fuck not really sure what this means
  - FOLLOW UP THOUGHT WITH SHAHR: Want to do problems where the stakeholders are a well defined group (neighborhood, particular group of people) who are underserved.
- "Methods in CBOR may vary widely, from traditional instances of prescriptive math models to a combination of qualitative and quantitative methods that may have much in common with related disciplines such as community planning, public health, and criminology." (p5)
- "One should immediately acknowledge the large literature in related fields of OR/MS, principally that of community operational research (Midgley & Ochoa-Arias, 2004a)"
  - THOUGHT: Need to find the large amounts of literature

- FOLLOW UP: Maybe there are problems that deal with community, but haven't been formulated in this way of CBOR (maybe?)

- Direct motivations for this textbook (and probably for CBOR)
  - importance of space, place and community in policy design and service delivery (this is for OR/MS in general)
  - a focus on disadvantaged, underrepresented, or underserved populations
  - international and transnational applications that go beyond the use of traditional models in non-US contexts

- CBOR benefits from multi-method, cross disciplinary, and comparative approaches and appropriate technology rooted in OR/MS
  - THOUGHT: Ok, but what does this actually mean?!?!?!

- Analytics is of use to CBOR? (how???? "supports a notion of generalized insight into problems of operations, uses a wide variety of quant. methods, and is intended to support changes in policy and practice")

- "Is there a way to do OR that balances positivist and quantitative approaches that dominate US-style practice with a more critical and subjective approach to decision modeling, that accommodates a variety of qualitative and mixed-methods?" (6)
  - THOUGHT: What does positivist mean? I need to understand this section better (or at all)
  - FOLLOW UP: Need to balance numbers-only approach (GDP goes up -¿ this is good!!!) vs more critical (Yeah GDP went up, but number of poor hasn't changed, etc)

- Is rigorous OR compatible with motivating values of social change and social justice?
  - THOUGHT: This is an **important question. If rigorous OR doesn't work to push social change and social justice then what is CBOR? What is the point? What does it imply for the discipline?**

- Can we develop a theory of CBOR that can provide guidance simultaneously to researchers who seek principles guiding diverse applications and practicioners who seek specific guidance to solve difficult real-world problems?
  - THOUGHT: whut

- Can CBOR yield research outputs that will find exposure in the most prestigious research journals and academic programs and thus influence the understanding of CBOR within the discipline???
  - THOUGHTS: WHAT!?!?!?! I need to spend more time on these questions

1.2 The Historical Context of CBOR and its Role Within OR/MS

- There are three trends in OR/MS that precipitated major disagreements regarding the proper role of OR in society
  - First trend: public service-oriented OR such as the Operations Research in Public Affairs program held at MIT in 1966, the Science and Techonlogy Task Force of 1967 that initiated quant. analysis of criminal justice problems, and the prevalence of quant. analysis used in the prosecution of the Vietnam War (?????what this mean).
  - Second trend: institutionalization of OR/MS within private-sector companies and the transition of OR/¡S from a transformational technology to one that increasingly focused on mathematical analysis and incremental gains in efficiency (YUCK!)
  - Third trend: Societal disenchantment with quant. methods that promised much, but (esp. considering vietnam war and social unrest in american cities) was not delivering on promise to improve society

- classic paper in OR by Russell Ackoff (1970) describes a primarility qualitative study to improve a poor minority neighborhood in philadelphia (in collab with local residents). ⇒ led to frustration with OR/MS discipline that placed emphasis on applied maths as against human processes, stylized quant. models vs systems-learning approach (p7)
- broader understanding of "problems" and social + political aspects of problem identification/solution, as opposed to focus on theory-building and algorithm development for stylized mathematical representations of the real world
  - THOUGHTS: so the conflict seems to be one of theory and practice. In OR/MS there seems to be an inclination towards theory and the abstraction of problems into mathematical formulations, but this doesn't really seem to work with CBOR
- decision problems as part of a social system rather than distinct entity that could be solved directly
- 30 years of disagreements between US-style OR (mathematical and problem-focused approach) and UK style (critical approach that closely examines roles of power, class, and community in defining problems amenable to OR/MS models and methods)
- alternatives: community operational research, soft-OR (WHAT IS THIS?!) and soft systems methodologies.
- difference in US and UK style OR can be attributed to economic recession experienced in UK in 70s and the larger role of socialist and marxist political movements. hard-OR still dominates in applied research in the UK though.
- public sector OR - centered on government and large nonprofit organizations - has played a role in OR/MS since beginning of discipline. Use traditional prescriptive and quantitative decision models.
  - text on urban OR by Larson & Odoni focused on urban operations and logistics issues without examining social processes that make urban problems different, did not address role of social policy in urban operations modeling
- Letter to the editor of *OR/MS Today* (2009) notes that "Soft OR" (also mentions PSM: problem structuring methods) papers are rarely published in major OR journals in US. (p8)
  - THOUGHTS: this seems important!! I should look up this letter.
  - Follow up point: apparently Mingers has some good shit on Soft-OR. Should look up : Mingers, J. (2009). Taming hard problems with soft OR. OR/MS Today, 36(2), 48-53. AND
    Mingers, J. (2011a). Soft OR Comes of Age - But Not Everywhere! Omega 39(6): 729-741.
- along with other factors (unclear profile for OR/MS, its uncertain status in business schools, uncertain employment prospects for those trained in OR/MS), an excessive focus on mathematical theory and analytical tools threatens long-term viability of OR/MS as a discipline (p8-9)
- the profile of CBOR in US degree-granting programs related to OR/MS and in top-tier journals is low, but has slightly increased in professional societies (particularly INFORMS).
- THE MILLION DOLLAR QUESTION: "Given the difficulty of addressing community-based problems in operations and strategy, is a rigorous mathematical basis for analysis the best or only way to do high-quality, cutting-edge research?" (p9)

1.3 Chapter Outline

- Section 2 - detailed survey of community operational research
- Section 3 - presents theory of CBOR that extends traditional notion of OR/MS inquiry
- Section 4 - summarizes published work related to CBOR that has appeared since 2007
  - THOUGHTS: Would be interesting to look at this

- Section 5 - updated assessment of CBOR profile within OR/MS across research, education, and practice
- Section 6 - contains thematic summary of 12 chapters in this textbook
  - THOUGHTS: definitely must look at this!
- Section 7 - concludes, identifies promising next steps for research within CBOR
  - THOUGHTS: should look at this too.

7 Book Chapters

A summary of the chapters in this textbook

7.1 Models and Analytic Methods

- Textbook "places special emphasis on research that develops new ways of abstracting real-life organizations, systems and processes into models, and designs and/or adapts novel analytic methods by which such models may yield prescriptions or policies that are relevant to practice" (p24).
- "Community-Based Operations Research" (Michael Johnson and Karen Smilowitz) - paper develops a theory of CBOR, presents a hypothetical CBOR application to urban public education, and reviews scholarly research in the field defined as CBOR starting in the early 1970s, discusess two actual CBOR applications and emphasizes linkages between applications and key elements of CBOR.
  - First application is programming model for design of delivery routes for donated food to food pantries that balances concerns of efficiency and equity.
  - Second application is a spatial decision support system providing guidance for low-income families who seek to relocate using rental housing vouchers, based on analysis of typical clients' ability to do elementary spatial analysis and analysis of decision alternatives, culminating in a prototype Web-based SDSS.
- "Operations Management in Community-Based Nonprofit Organizations" builds theory, identifies applications and makes links to other disciplines in exploring how the supply chain can be applied to nonprofit sector.
  - chapter divided into topics that correspond to three portions of supply chain. The first (supply/inputs) is represented by fundraising, earned income, foundation grants. The second (nonprofit production/acitivities) is organized according to objectives, coordination and centralization, and production processes by which services are provided to client populations. The last category (consumers and markets of nonprofit goods and services) looks at role of supply & demand in decisions regarding resource acquisition, service design and collaboration and competition, and how the work of nonprofits can be quantified and evaluated using principles of performance measurement.
  - chapter concludes by summarizing similarities and differences between for-profit supply chains and nonprofits providing goods,services for public good. also identifies promising areas of future research, including role of risk, multiple organizational objectives, interplay between for-profit and nonprofit orgs and services
- "Modeling Equity for Allocation in Public Resources" provides theoretical foundation for consideration of equity as co-equal criterion for allocating public resources along with traditional concerns of effectiveness and efficiency
  - authors define equity as addressing three elements: resources to divide between recipients, sets of recipients by which resources will be divided, and time periods across which resources are provided
  - they define fundamental distinction between equity of resource allocation process ("*ex ante* equity") and equity of outcomes produced by the process("*ex post* equity"), and show that allocations may be ex ante equtiable but may not be ex post equitable, and vice versa.

        * concepts illustrated using example from emergency medical services: uncertainty plays a fundamental role in service delivery time and patient survival
        * THOUGHT: I think ex post equitable is more important
    - authors provide illustrative mathematical formulations of equity objectives and discuss issues of mathematical tractability and incorporation into multi-objective mathematical programs.
        * They recommend other researchers extend work through systematic analysis of equity objectives, investigation of the implications of use of equity as a constraint rather than an objective in math programming models, incorporation of process equity in operations research models, development of a "toolbox" of a core set of equity functions of broad applicability to OR/MS, and investigation of how equity can be incorporated into things besides EMS

- THOUGHTS: the first and third chapters in this section seem like they might be helpful. The first chapter gives two applications and more concretely lays out CBOR. the third chapter talks about equity, and how it may vary depending on whether its an objective function or merely a constraint. They also provide mathematical formulations of equity objectives which is definitely something I would want to take a look at.

7.2 Facility Location and Spatial Analysis

- Since services (and their facilities) have spatial extent, issues of spatial distribution of client populations and proximity of clients to service providers (+ways they are measured and policy implications) are important

- "Spatial Optimization and Geographic Uncertainty: Implications for Sex Offender Management Strategies" related to work on decision models for measuring spatial impact of rigorous enforcement of laws relating to allowed residential locations for sex offenders
    - authors examine nature of measurement itself in geographic information systems, discuss impact upon residential prescriptions for sex offenders of uncertainty in approximating proximity and physical location within GIS
    - four categories of uncertainty: object geometry, data precision, distance measurement, proximity interpretation. authors propose improvement of data/model quality along each dimension, in addition to changing language of statues
    - want to ensure laws are designed and enforced effectively + fairly
    - THOUGHTS: this sounds like it could be iffy tbh

- "Locating Neighborhood Parks with a Lexicographic Multiobjective Optimization Method" - spatial decision modeling
    - authors address issue of identifying and assembling land parcels in urban areas into parks to meet requirements of parkland per resident (and because of documented benefits of parks)
    - discrete multi-objective facility location problem, objectives being geographic coverage, level of, and proximity of parks to, positive and negative local externalities, number of beneficiaries, physical accessibility, total cost, subject to limits on total size of park as well as of component parcels
    - apply an ϵ-constraints approach as well as a priori lexicographical ordering of decision criteria to measure and control deviation of objective values from best-possible values across various feasible sols.
    - applied to urban park planning in Bogota
    - show that model instances can be designed with acceptable level of technical difficulty
    - solutions generated show variations in performance across multiple objectives, as well as spatial and policy impacts of alternative park infrastructure strategies

- "Using GIS-Based Models to Protect Children from Lead Exposure" represents strongest link to themes of minority, disadvantaged groups, and service delivery

  - significant negative health impacts to children due to lead exposure (primarily due to lead-based paint)
  - authors introduce model to measure levels of childhood residential lead exposure
  - uses GIS to assemble spatial data on residential parcels, associates parcels with data on risk factors for childhood lead exposure and geocoded blood surveillance data
  - data used in regression model to forecast lead exposure at parcel level
  - model has been used by orgs to design localized lead poisoning prevention strategies (targeted blood screening, lead paint abatement and educational programs, community outreach)

- THOUGHTS: I don't know how useful the first chapter in this section may be. The second chapter may be of interest because of the multiple objectives (I don't even know what that would look like!). Third one does not really interest me.

Facility Location and Spatial Analysis
Ch6: Locating Neighborhood Parks with a Lexicographic Multiobjective Optimization Method

1 Introduction

- Lists benefits to parks (better physical & mental health, quality of life, etc)
- Four types of parks: pocket, neighborhood, zonal and metropolitan (based on size and types of activities facilitated within)
- pocket parks $< 1000m^2$, dedicated to passive recreation
- neighborhood parks are dedicated to active recreation and community integration
- pocket and neighborhood parks only serve one neighborhood
- zonal parks - passive and active recreation for several neighborhoods
- metro parks ($> 100000m^2$) - passive & active rec. for the whole city, landscape and environmental benefits too
- sports and recreation master plan (2006) - by 2019, city must reach minimum level of neighborhood park area of $2.71m^2$ per inhabitant
- Instituto Distrital de Recreacion y Deporte (IDRD) in charge of this project
- BUT! locating green areas is complex because need to balance compromise among geographic, social, and economic criteria $\rightarrow$ multiobjective optimization approach!!!
- large number of candidate parcels, virtually infinite number of possibilities (every subset is possible solution)
- they propose multiobjective facility location model linked to a GIS that interacts with decision makers to determine which parcels should become new parks
- proposed location model considers: number of beneficiaries, geographic coverage, sidewalk and road accessibility, connectivity with other facilities, positive & negative externalities provided by nearby facilities, construction and parcel acquisition cost

2 Literature Review

IDRD problem relates not just to selection of parcels to be turned into parks, but also to the selection and calculation of the evaluation criteria.

2.1 Criteria for Evaluating the Quality of a Park

- people value accessibility, usually measured as distance from their home to park
- person defined to have access to park if they live within park's service area (within a maximum distance from the park's centroid or boundary)
- has been well documented that distance is the main reason for not visiting the nearest park, and that people living close to a park tend to visit it more often
- however, service area ignores how individuals reach the park. Some authors have considered the number of sidewalks or roads as a complementary measure of accessibility
- number of potential users (number of inhabitants living in park's area of influence) been used as measure of park's quality
- authors have proposed index of park service based on the fraction of people within area of analysis that is affected by parks
- as park size increases, more people willing to visit
- other measures of park quality: available infrastructure (sport facilities, paved trails, lakes), landscape and ecological features, and non-aesthetic attributes (perception of safety)
- in Bogota, IDRD planners identified additional quality measures, such as connectivity with existing facilities in city (bus rapid transit - BRT - stations) and externalities provided by nearby facilities (schools, etc).

2.2 Location of New Parks

- discrete facility location problem!
- literature on locating public facilities is rich and their methodologies have been successfully applied in locating disaster recovery centers, fire stations, park-and-ride facilities, depots in the coffee supply chain, hospital waste management facilities, and healthcare facilities (among others)
- Mentions a good overview and introduction of facility location: surveys by Owen and Daskin (1998), Daskin (2008), ReVelle and Eiselt (2005), and ReVelle, Eiselt, & Daskin (2008). For a survey on multiobjective facility location, the author mentions Farahani et al (2010).
- few researchers have dealt with locating new parks. and their applications not helpful for large scale projects

3 Evaluation of Candidate Parcels

- candidate parcels evaluated through indices comprising info along five axes:
  - geographical coverage
  - number of beneficiaries
  - sidewalk and road accessibility
  - nearby facilities
  - cost
- these critera were agreed upon by consent on meetings with urban planners from IDRD and other metropolitan offices such as Secretaria Distrital de Pleneacion - SDP (metropolitan planning office) and Taller del Espacio Publico (Public Space Committee), following the guidelines of Bogota's strategic master plan for parks
- all indices except cost calculated based on service area of candidate parcel

- service area calculated using centroid radii or buffer method as a circular area of radius r from the parcel's centroid
    - THOUGHTS: what this mean?
- the radius of influence (r) can be a fixed distance or a function of the parcel's area

3.1 Geographical Coverage

- calculated as number of blocks in parcel's service area, used as proxy of potential access to the park system
- a large index means a service area covering a large number of blocks
- this index ignores the density of people living in the service area
- mitigates uncertainty related to population growth or changes in urbanization patterns
- analysis based solely on number of beneficiaries will suggest building parks in dense areas, ignoring areas under development or likely to experience fast population growth
- by covering as many blocks as possible, guarantee access to current and future beneficiaries
- counting residential blocks is better than covered area because it avoid affecting index by effect of open spaces with no direct beneficiaries (ie. large industrial facilities, roads)

3.2 Number of Beneficiaries

- this index quantifies the potential number of park users
- measures population in service area to promote parcels benefitting a lot of people
- focused on low income area of city, so number of beneficiaries a good indicator of social impact of park (??)

3.3 Accessibility

- index based on density of sidewalks and roads that make the park accessible
- given a park's service area, accessibility index is calculated as the total length of sidewalks and roads per square meter
- normalize the accessibility of a park by dividing it over accessibility index of the whole area of analysis, thus an index greater than one represents that the park is relatively more accessible than the rest

3.4 Connectivity

- index a measure of connectedness between candidate parcel and existing nearby urban facilities
- facilities classified into one of two groups:
    - facilities that could potentially harm the perceived benefits of the park (provide a negative externality) e.g., jails and morgues
    - facilities that could potentially increase benefits of park (provide a positive externality) e.g., schools and BRT stations
- connectivity index calculated by subtracting number of facilities with a negative externality from the number of facilities with a positive externality within the park's service area
- index greater than zero means park is expected to capture some extra benefits

- purely a count, since no primary information available to state relative importance of the externalities provided by each facility
- could be modified (if such info exists) by including a weight that reflects the relative importance of each positive or negative externality into a weighted aggregated index

3.5 Weighted Proximity to Externalities

- index considers nearby facilities weighted by their proximity
- assumes the effect of externalities reduces as the distance from the parcel increases
- r^e denotes the maximum radius of influence for externalities, d the radial distance of the facility to the parcel
- facilities closer than r^e have weight of $1 - \frac{d}{r^e}$
- as with connectivity index, you subtract negative externalities from positive ones
- could also incorporate an importance weight

3.6 Cost

- Total cost is parcel acquisition cost plus the construction costs of the park.
- first component is estimated according to real estate appraisals
- second component includes construction materials, amenities (swing, slides), design, operations, and administrative obligations

4 Optimization Model and Solution Strategy

4.1 Model

- $\mathcal{I}$ denotes the set of candidate parcels, partitioned into two sets:
  - $\mathcal{I}_\mathcal{F}$ contains parcels with an area less than or equal to $10000m^2$ (fixed-size parcels)
  - set $\mathcal{I}_\mathcal{V}$ contains larger parcels (variable-size parcels because effective park area is yet to be determined)
- model formulation considers set of existing urban facilities $\mathcal{E}$
  - $\mathcal{E}_\mathcal{P}$, the set of facilities with positive externalities
  - $\mathcal{E}_\mathcal{N}$, the set of facilities with negative externalities
  - $\mathcal{E} = \mathcal{E}_\mathcal{P} \bigcup \mathcal{E}_\mathcal{N}$, $\mathcal{E}_\mathcal{P} \bigcap \mathcal{E}_\mathcal{N} = \emptyset$
- circular service area of parcel i is defined by its radius r_i measured from its centroid
- let $\mathcal{J}$ be the set of all blocks serviced by at least one candidate parcel, or rather, $\mathcal{J}$ contains all blocks that could potentially benefit from the construction of new parks
- the set of all candidate parcels servicing block $j \in \mathcal{J}$ is defined by $\mathcal{W}_j$
- candidate parcel i belongs to set $\mathcal{W}_j$ if block j is within r_i from parcel's centroid
- p_i, the number of beneficiaries from candidate parcel i
- v_i, the accessibility index of candidate i

- e_i, connectivity index of parcel i
- c_i^l, the parcel (lot) acquisition cost
- c_i^b, the construction cost for candidate parcel i
- to calculate the proximity externality index, let d_{ik} be the distance between parcel i and facility k ($k \in \mathcal{E}$) and recall r^e is the max radius of influence of the externalities of a given facility
- a_i, the area in square meters of parcel i
- $\underline{a}$, the minimum area of parks required to accomplish Bogota's master plan
- $\bar{a}$, the maximum area of parks that could be handled by IDRD, it is a proxy of their management and financial capacity during the planning horizon
- in case of selecting variable-size parcels, parameters $\underline{s}_i$ and $\bar{s}_i$ ($i \in \mathcal{I}_\mathcal{V}$) represent the min and max construction areas for the new park i
- the model identifies the candidate parcels that should be transformed into parks
- binary decision variable y_i: takes value of 1 if candidate parcel i is to be transformed into a park, 0 otherwise
- for variable-size areas, x_i represents the area of the candidate parcel i that is to be transformed into a park.
- binary variable z_j takes the value of 1 if block $j \in \mathcal{J}$ is covered by at least one park, 0 otherwise.
- The model is as follows: (and has 6 objective functions)

THE MODEL!

$$\max\ f_1 = \sum_{j \in \mathcal{J}} z_j \tag{1}$$

This maximizes the geographical coverage of the parks.

$$\max\ f_2 = \sum_{i \in \mathcal{I}} \left(\sum_{\{k \in \mathcal{E}_\mathcal{P} : d_{ik} \leq r^e\}} \left(1 - \frac{d_{ik}}{r^e}\right) y_i - \sum_{\{k \in \mathcal{E}_\mathcal{N} : d_{ik} \leq r^e\}} \left(1 - \frac{d_{ik}}{r^e}\right) y_i \right) \tag{2}$$

This maximizes the externality proximity index (the impact from facilities near the park. The left sum inside parenthesis takes all the positive facilities ($k \in \mathcal{E}_\mathcal{P}$), and makes sure that the distance from the facility to the park is within the facility's area of influence ($d_{ik} \leq r^e$), and then sums over the value $\left(1 - \frac{d_{ik}}{r^e}\right) y_i$ which calculates the ratio of distance from park to facility, subtracts it from 1, and then multiplies it by y_i, or whether a park is being built there or not. So this calculates all the positive externalities for ONE specific (park) lot, and subtracts from it the negative impact of all the facilities. The sum outside parenthesis just tells us that we need to do this for EVERY candidate lot.

$$\max\ f_3 = \sum_{i \in \mathcal{I}} p_i y_i \tag{3}$$

This maximizes the number of beneficiaries.

$$\max\ f_4 = \sum_{i \in \mathcal{I}} v_i y_i \tag{4}$$

This maximizes the accessibility index

$$\max\ f_5 = \sum_{i \in \mathcal{I}} e_i y_i \tag{5}$$

This maximizes the connectivity index

$$\min\ f_6 = \sum_{i \in \mathcal{I}} (c_i^l + c_i^b) y_i \tag{6}$$

This minimizes the total cost.

SUBJECT TO

$$z_j \leq \sum_{i \in \mathcal{W}_j} y_i, j \in \mathcal{J} \tag{7}$$

This guarantees that if block j is covered, then at least one candidate parcel covering the block has been selected as a park.

$$|\mathcal{W}_j|\, z_j \geq \sum_{i \in \mathcal{W}_j} y_i, j \in \mathcal{J} \tag{8}$$

If block j is not covered, then none of the candidate parcels serving it should be selected.

$$\sum_{i \in \mathcal{I}_{\mathcal{F}}} a_i y_i + \sum_{i \in \mathcal{I}_{\mathcal{V}}} x_i \geq \underline{a} \tag{9}$$

This just means that the park area should meet the minimum requirements of the master plan.

$$\sum_{i \in \mathcal{I}_{\mathcal{F}}} a_i y_i + \sum_{i \in \mathcal{I}_{\mathcal{V}}} x_i \leq \bar{a} \tag{10}$$

Just sets the upper bound for the previous constraint, which ensures that they do not have more parkland than the IDRD can handle.

$$\underline{s}_i y_i \leq x_i \leq \bar{s}_i y_i, i \in \mathcal{I}_{\mathcal{V}} \tag{11}$$

The allotted park area should be within the min and max construction size parameters. (size limit on variable size parks)

$$y_i \in \{0, 1\}, i \in \mathcal{I} \tag{12}$$

Is a binary decision variable: 1 if parcel i is selected, 0 otherwise.

$$z_j \in \{0, 1\}, j \in \mathcal{J} \tag{13}$$

Another BDV. If block j is covered by park then 1, otherwise 0.

$$x_i \geq 0, i \in \mathcal{I}_{\mathcal{V}} \tag{14}$$

Nonnegativity constraint on variable sized park area.

Apparently the first objective function and the first set of constraints close resemble a maximal covering model, where the blocks are customers and new parks the facilities (what is a maximal covering model??). Constraints 3 and 4 impose a limit on the number of facilities.

4.2 Solution Strategy

- ϵ-constraints approach combined with an a-priori lexicographic ordering of the decision criteria
- allows decision makers to interactively incorporate their preferences as long as decision criteria are optimized under lexicographic order
- proposed interactive solution narrows the set of possible solutions to only those with a good compromise of objectives
- methodology divided into two stages
  - In first stage, each of the objectives is optimized in isolation, subject to the constraints (henceforth referred as Ω
  - the optimal value of each objective function in the first stage is denoted by $f_k^*(k = 1, 2, \ldots, 6)$
  - In the second stage, incorporate a lexicographic ordering of the objectives
  - order was established jointly with IDRD planners based on their experience and aligned with the sports and recreation master plan for the city
  - planners stated order of objectives as they are presented
  - compromise threshold defined for each objective, denoted by $(1 - \alpha_k)$, where α_k represents the maximum acceptable deterioration of objective $k = 1, 2, \ldots, 5$.
  - no compromise threshold assigned to last objective in lexicographic order, as it corresponds to last optimization model to be solved
  - cost was defined as last objective as it was implicitly included in two constraints
- second stage proceeds as follows:
  - we solved a model to optimize the second objective function subject to the set of constraints Ω.
  - to consider the compromise threshold of $100(1 - \alpha_1)\%$ for f_1^* we add the constraint:

$$\sum_{j \in \mathcal{J}} z_j \geq (1 - \alpha_1) f_1^*$$

  - this constraint guarantees that the new solution covers at least $100(1-\alpha_1)\%$ of the maximum number of covered blocks given by f_1^*.
  - next, solve a model to optimize the third objective, considering the set of constraints Ω, the constraint we just added, and this constraint:

$$\sum_{i \in \mathcal{I}} \left(\sum_{\{k \in \mathcal{E}_{\mathcal{P}} : d_{ik} \leq r^e\}} \left(1 - \frac{d_{ik}}{r^e}\right) y_i - \sum_{\{k \in \mathcal{E}_{\mathcal{N}} : d_{ik} \leq r^e\}} \left(1 - \frac{d_{ik}}{r^e}\right) y_i \right) \geq (1 - \alpha_2) f_2^*$$

  - this new constraint guarantees that the new solution reaches at least $100(1-\alpha_2)\%$ of the maximum externality proximity index. this solution also guarantees a minimum level of geographical coverage through the first set of constraints we added
  - next, the fourth objective function is optimized subject to the original constraints (omega), the two new constraints and the following constraint:

$$\sum_{i \in \mathcal{I}} p_i y_i \geq (1 - \alpha_3) f_3^*$$

  - this constraint limits the deterioration of the objective regarding the number of beneficiaries beyond $\alpha_3\%$.

- then, objective five is optimized subject to all the previous constraints plus this one:

$$\sum_{i \in \mathcal{I}} v_i y_i \geq (1 - \alpha_4) f_4^*$$

- this constraint avoids the deterioration of the accessibility index beyond its maximum accepted compromise of α_4%
- the sixth objective is then optimized subject to Ω, the previously added constraints, and this one:

$$\sum_{i \in \mathcal{I}} e_i y_i \geq (1 - \alpha_5) f_5^*$$

- this constraint guarantees a solution with at least $100(1 - \alpha_5)$% of the max connectivity index.

- depending on the quality of the intermediate solution, the planners can change the compromise thresholds for the already optimized objectives
- for instance, if the last objective is optimized and the quality of the solution is not deemed satisfactory, the planners can update the values of α_1 thorough α_5 to try to improve the quality of the current objective compromising the most important ones
- Or, the planners may choose to make the compromise thresholds tighter to improve the solution under the light of the most important objectives, sacrificing the quality of the current (less important) objective

DIFFERENT BOOK - Introduction to Operations Research

1 Introduction

1.1 The Origins of Operations Research

- Because of war effort, need to allocate scarce resources to various military operations and to activities within each operation in effective manner
- British and US military asked scientists to do *research on* (military) *operations.*
- Developed effective methods of using radar (new), research on how to better manage convoy and antisubmarine operations, etc.
- Success of OR in the war encouraged interest in non-military applications
- Substantial progress was made early in improving the techniques of OR, which led to rapid growth of field
  - One example is the *simplex method* for solving linear programming problems
  -

HISTORY OF OR IN US MILITARY

0 Preface

- "US Army" refers to all of the army structure, including military and civilian, and includes army air forces until creation of separate US air force in 1947
- starting date for this study: 1942
- US Department of Defense definition for OR: "The analytical study of military problems undertaken to provide responsible commanders and staff agencies with a scientific basis for decision on action to improve military operations".
  - note that this definition excludes any mention of mathematics
  - defined 5 essential components of OR: definition of the problem, collection of data, analysis of the collected data, determination of conclusions, final recommendation (for course of action)
- this volume focuses on the first two of these four principal applications of OR to military:
  - development, testing, and performance evaluation of weapons and other equipment
  - design and evaluation of military organizations, tactics, strategy, methods and policy
  - the evaluation of human performance and behavior
  - the design and evaluation of effective management structures and procedures

0.1 Prologue

This section makes reference to "classical and early modern antecedents of OR", mentions that Archimedes may just be the patron saint of OR? Also talks about the scientific analysis of the napoleonic wars, and the emergence of military OR in WWI.

1 Ch1: Operations Research in WWII.

- Development of radar necessitated the search for effective techniques for its use, and this is how the science of OR emerged
- once war began, british armed forces began to create OR units to find solutions to urgent technical and operational problems
- after pearl harbor, US armed forces began to establish OR units

1.1 Radar and the origins of operational research

- in 1934, as nazi germany denounced the disarmament clauses of the treaty of versailles, britain raced to strengthen its defenses
- In spring of 1934, one of the workers in the Air Ministry (A.P. Rowe, assistant for armaments) iidentified the urgnedt need for an effective early warning system against enemy aircraft
- By 1935 radar had been developed and demonstrated capable of deetecting unknown aircraft
- the utility of radar, however, became dependent on its ability for integration with the existing system of ground observers, interceptor aircraft, and antiaircraft artillery positions
- Alan's note: this section doesnt seem to be very mathematical, and is more about the use of scientific, rigorous processes to develop a system for the incorporation of radar.

1.2 OR in the british armed forces, 1939-1945

- By 1941, recognizing the work of the OR group with radar, more OR sections began to be established throughout air force, army, ground forces.
- the requirements for OR work were having a: "scientific mind" attuned to questioning assumptions, devising and testing hypotheses by means of logic and experimentation, collecting and analyzing large quantities of diverse data, and formulating effective solutions.
- "Dr. Ward F. Davidson concluded that only approximately 20 percent of the OR work undertaken by the British up to mid-1942 required "specialized scientific knowledge or advanced mathematical training," and that such knowledge and training were less necessary when the project involved the analysis of operational systems ("true operational analysis") rather than the more technical study of specific weapons." (p11)
- the integrated radar-based air defense system led to the victory of the RAF in the Battle of Britain
- radar increased the probability of intercepting an enemy aircraft by a factor of 10 (p12)
- operation analysts at Stanmore also investigated other problems: enemy bomber and escort tactics, procedures for night operations, including the development of ground control intercept equipment and methods, the most profitable use of weapons under various conditions, and the effects of weather and other factors on defensive air operations.
- During battle in France in may 1940, OR team was called upon to influence high-level strategic policy aking when the French requested additional RAF fighter support. Churchill was inclined to accept this request but the OR team showed that "additional transfers would involve attrition that could not be made good and that Fighter Command would be weakened beyond recovery in the face of the likelihood of a German attempt to invade Britain". Churchill, convinced by the presentation, did not send reinforcements, preserving aircraft for the battle of britain.
- this involvement of analysts in matters of higher policy marked a change for OR, as it would be used to predict the outcome of future operations with the objective of influencing policy.
- Another STRIKING accomplishment of OR analysts was the work on depth charge settings, which led to an immediate improvement of aerial attacks on German submarines. estimates of the increased efficiency range between 400 and 700 percent, significantly diminishing U-boat activity around the British Isles in the last half of 1941.
- Other OR work included the developments to reduce the number of rounds required to down one German aircraft (by aircraft artillery) from 20 thousand in the summer of 1941 to only 4 thousand in 1942.
- from the Brits it spread to the americans
- used it in the battle of the pacific, the Mine Warfare Operations Research Group (MWORG, formed 1942) promoted mine laying by aircraft, mining campaign called operation STARVATION, referred to as "the most complete single example of the successful application of military operations-research techniques during the war" (p21).
- OR also used in air force, ground forces, service forces
- "the new " science" of operations research played a substantial role in winning World War II" (p41)

PLANNING PROBLEMS IN THE USSR

1 Introduction: The use of mathematics in soviet economics- an historical survey

- “Much of the ‘new’ Western economics of the post World War II period, such as the discussion of the economic problems of the developing countries, growth models and input-output, was simply the rediscovery and development of the fruitful Soviet work of the 1920s”. (p1)
- In 1928, L.P. Yushkov discussed what later became a central problem of theory of the optimally functioning socialist economy; how to create a system of planning that would provide the ‘semi-automatic optimality’ of the development of the national economy, combining optimal national economic development with maximal operational indepednence for the separate parts of the econmic system
- ?

Citation info: Title: Planning Problems in the USSR; the Contribution of Mathematical Economics to their Solution 1960-1071
Author: Michael Ellman
Cambridge University Press 1973

Pareto Multi Objective Optimization

1 Introduction

- optimization essential process in many business, management, and engineering applications
- in these fields, multiple and often conflicting objectives need to be satisfied
- such problems traditionally consist of converting all objectives into single objective function to min/max by aggregating all objectives into weighted function, or transforming all but one objective into constraint, which has limitations:
  - requires a priori knowledge about relative importance of objectives, and the limits on objectives that are converted into constraints
  - aggregated function leads to only one solution
  - trade-offs between objectives cannot be easily quantified
  - solution may not be attainable
- simply unacceptable for complex systems!
- in business world known as "trade-off analysis"
- compared to single objective problems, multi objective problems harder to solve, because no unique solution
- rather, a set of acceptable trade-off optimal solutions
- this set called the Pareto front
- Multiobjective optimization considered the analytical phase of the "multi criteria decision making" (MCDM) process
- the preferred solution, the most desirable one to the designer or decision maker (DM) is selected
- Generating Pareto set allows Decision Maker (DM) to make informed decision by seeing wide range of options
- utopian solution is the solution that is optimal for all objectives
- DEFINITION: "a solution belongs to the Pareto set if there is no other solutionthat can improve at least one of the objectives without degradation any other objective" (p85)
- "a decision vector $\bar{u} = [u_1, u_2, \ldots u_n]^t$ is said to *Pareto-dominate* the decision vector $\bar{v} = [v_1, v_2, \ldots, v_n]^t$, in a minimization context, if and only if for all $i \in \{1, \ldots, N\}, f_i(\bar{U}) \leq f_i(\bar{v})$, and there exists a $j \in \{1, \ldots, N\} : f_j(\bar{u}) < f_j(\bar{v})$." (p85) ($f_i$ denotes the objective function)
- a solution is Pareto optimal iff there does not exist another solution that dominates it, which means that a solution $\overrightarrow{a}$ is pareto optimal if it cannot be improved in one of the objectives without adversely affecting at least one other objective.
- generally impossible to come up with analytical expression of the pareto front
- solution approaches for solving multiobjective problems:
  - converting MO problem into SO problem (assume a priori information from the DM)
  - second class of techniques geared towards direct determination of Pareto frontier by optimizing all the objectives separately

- Classical methods: consist of converting MO problem into SO problem by either aggregating objective functions or optimizing one objective and treating other as constraints (this is similar to what we did but not QUITE THE SAME!)
- weighted aggregation!! converts MO problem into an SO problem by applying a function operator to the objective vector, a simple + popular function being a linear combination of objectives: Minimize $Z = \Sigma_{j=1}^{N} w_j f_j(\overrightarrow{x})$ with $w_j \geq 0$ and $\Sigma_{j=1}^{N} w_j = 1$. the weights (w_j) can indicate relative importance that DM attaches to objective j and must be specified beforehand. But this method yields one result that largely depends on the selection of the weights, and without prior information, the selection of the weights can be problematic.
- Goal programming (a variation of the above!) seeks to minimize deviation from prespecified goals. Minimize $Z = \Sigma_{j=1}^{N} w_j |f_j(\overrightarrow{x}) - T_j|$, where T_j represents the target or goal set by the DM for the jth objective function, and w_j are the priorities. but you still need a priori information.
- ϵ-Constraint approach (this is what we did)! this is computationally intensive, but a simple technique
- for all these solutions to generated front while locally non-dominated is not necessarily globally non-dominated
- Intelligent techniques: geared towards direct generation of pareto front by simultaneously optimizing the individual objectives
- Evolutionary computing emulates biological evolution process; a population of individuals representing different solutions is evolving to find optimal solutions; fittest individuals chosen, mutation and crossover operations applied, yielding a new generation offspring.
- genetic algorithms, evolutionary algorithms, evolutionary strategies
- non-pareto-based approach: vector evaluated genetic algorithm (VEGA)
- pareto-based approaches:
- multi objective genetic algorithm: fitness value of an individual is proportional to the number of other individuals it dominates
- non-dominated sorting genetic algorithm (NSGA): layered classification technique. non-dominated individuals are assigned the same fitness value and sharing is applied in decision variable space
- Niched Pareto Genetic Algorithm (NPGA): two individuals are compared with respect to a comparison set; when one candidate dominated by set while other is not, latter is selected. If neither or both are dominated, fitness sharing used to decide selection.
- Strength Pareto Evolutionary Algorithm (SPEA) uses external archive to maintain non-dominated solutions found during the evolution.
- Multi Objective Particle Swarm Optimization (MOPSO)
- Modern methods allow concurrent exploration of Pareto front, can thus generate multiple solutions in a single run. main drawback is performance degradation as number of objectives increases, since there does not exist computationally efficient methods to perform pareto ranking.

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