1-1-2010

Housing and Community Development

Michael P. Johnson Jr.
University of Massachusetts Boston, michael.johnson@umb.edu

Housing and Community Development

Journal:	*Wiley Encyclopedia of Operations Research and Management Science*
Manuscript ID:	EORMS-09-0181.R1
Wiley - Manuscript type:	Introductory
Date Submitted by the Author:	
Complete List of Authors:	Johnson, Michael; University of Massachusetts Boston, Public Policy and Public Affairs
Keywords:	affordable housing, community development, decision models, sustainable development, urban affairs

Housing and Community Development

Michael P. Johnson
Department of Public Policy and Public Affairs
University of Massachusetts Boston
Boston, MA 02125-3393
michael.johnson@umb.edu

Revised January 4, 2010

Submission to *Encyclopedia of Operations Research*

Abstract:

Researchers in housing and community development design and evaluate policies regarding access to attractive, affordable and sustainable housing and improving the social, physical and economic infrastructure of communities, especially those in the urban core. Practitioners in this field confront political considerations, administrative guidelines and limited funding.

Decision science can increase the efficiency and effectiveness of market-rate housing development and provide support for policy responses to issues such as affordable housing, race and class segregation, ineffective and/or inequitable economic development, and sustainable development. This research spans many disciplines, including systems modeling, urban economics, multi-criteria decision modeling, stochastic models and decision support systems, and is often interdisciplinary and applied in nature. A common thread in this work is the need to explicitly address the needs of multiple stakeholders, to capture the public and private nature of housing, and to incorporate best-available evidence regarding markets, policies and impacts of housing and community development.

We describe the policy context for this work, review previous research through the lens of descriptive, prescriptive and decision support models, and identify important limitations to work in this area to date. We then describe diverse opportunities for research in this area that can address current policy concerns such as sustainable development, post-disaster reconstruction and individual and group decision support.

Keywords:

Housing markets, affordable housing, subsidized housing, community development, decision models, decision support systems, sustainable development, urban affairs

Housing is a key component of the U.S. economy: in 2001, housing comprised more than a third of the nation's tangible assets, and housing consumption and related spending represented more than 21 percent of the U.S. gross domestic product [1]. Housing that is decent-quality and *affordable* is associated with increased household wealth, family stability, mental and physical health, labor market participation, educational achievement and neighborhood quality [2]. Decent and affordable housing also contributes to the improved physical, economic, environmental and social health—the *sustainability*—of communities. These impacts are especially important for lower- income and disadvantaged households.

The benefits of housing, and of sustainable communities, are unequally distributed, however. Examples include: increases in renters in market-rate housing paying excessive fractions of incomes in rent or living in severely substandard housing [3], shortages in affordable and "workforce" housing [4], flat or declining funding levels for public housing authorities [1], persistent gaps in homeownership rates by race and ethnicity [5], excessive housing and transportation burdens on working families [6], [7], [8], challenges in economic revitalization facing older urban centers [9] and displacement of the urban poor as a consequence of public housing renovation and economic renewal [10]. These concerns are summarized as inequalities across class, race and ethnicity in the "geography of opportunity" linking housing, schools, employment and other services [11].

Most recently, the U.S. economic recession of 2007 – 2009 [12] has had adverse effects across the economy, particularly residential housing. Since 2005, there have been substantial decreases in median housing values, home equity, existing home sales, mortgage refinances, total housing starts and new home sales and substantial increases in home mortgage delinquencies and foreclosures [13]. It is estimated that American homeowners have lost more than $4 trillion in wealth associated with housing equity between July 2006 and July 2008 [14]. Foreclosures resulting from the housing market decline are associated with increased crime, decreased property values and losses in tax revenues [15]. These negative impacts have been borne disproportionately by communities in the west, southeast, upper Midwest and portions of the Northeast, low- and middle-income households, and black and Hispanic households [13]. The foreclosed housing crisis, combined along with longer-term adverse trends in rental housing, has resulted in increased pressure on the rental housing market and a mismatch between affordable rental housing supply and demand [16].

Public policy analysis and design can increase the efficiency of market-rate housing production. It can also reduce the magnitude of inequities within housing markets, as well as inequalities related to housing-related social outcomes. Management science and operations research, and related disciplines, can help determine when, where, what type and by what means affordable housing and sustainable communities might be built, redeveloped and maintained. This article argues that current decision modeling research that is interdisciplinary, that combines descriptive and prescriptive perspectives, and that addresses the needs of diverse stakeholders, policy objectives and policy actions may provide specific, actionable guidance to address housing-related social inequalities and housing policy generally. Most of the policy motivation and definitions, and much of the research described in this article, reflects a U.S. perspective.

We review a number of key definitions used throughout this article. “Subsidized” and “assisted” housing refers to housing intended for low- and moderate-income families (in the U.S., typically, those with incomes at or below 80% of the area median income). Such housing is produced with funds or incentives provided by Federal, state or local governments. Means by which this is done for rental housing include government ownership and operation of newly-built housing; government contracts or tax credits with private developers to produce housing, or direct subsidies to families to secure private-market housing on their own [17]. Owner-occupied housing can be produced using mortgage interest and real estate tax deductions, below-market interest rate mortgages and mortgage insurance and support for government-sponsored enterprises that increase market demand for affordable housing financing instruments [4].

“Affordable” housing is targeted at middle- and lower-income families (typically, those with incomes at or below 120% of the area median income) and which does not consume more than 30% of a household’s income. Such housing, whether renter- or owner-occupied, may receive direct support from government sources, as for subsidized/assisted housing, or may be provided in exchange for economic incentives provided by political jurisdictions or entities responsible to them, or to conform with zoning rules [4]. “Workforce housing” is affordable housing intended specifically for households whose members provide essential municipal services [18].

Housing and communities can be economically, socially or environmentally “sustainable” [19]. For example, public policies or design standards may reduce the negative environmental impacts, such as energy consumption or pollution, of residential and community development [20]. Also,

public policies or design standards may enable diverse families to live in housing and neighborhoods that allow broad access to economic and social mobility. Such communities may have the potential to smoothly adapt to changes over time in employment, infrastructure and demographics.

Decision models for housing and community development build on research and best practices in supply and demand analysis, land acquisition, construction and management. However, these models, though numerous, diverse, and well-represented in high-quality scholarly research outlets, have not achieved their potential in policy and practice. Why, then, are they worth studying?

First, these decision models are policy-relevant. They address problems that affect choices or resources of individual families ("person-based" strategies) as well as problems that affect physical infrastructure or human resources of entire communities ("place-based" strategies) [21]. They address important policy and practice concerns such as minimizing costs, maximizing benefits, maximizing geographic deconcentration, and maximizing fair access to affordable housing and sustainable communities. Second, decision models may provide direct assistance to urban and regional planners who rely on more traditional methods such as land-use zoning, subdivision regulation, growth management, smart growth, equitable development, and inclusionary zoning [22]. Finally, decision models may generate recommendations that balance national-level policy priorities, such as: creating new housing choices, protecting current housing choices, and changing attitudes and preferences regarding housing choice [11].

Analysis of the research literature in decision models for housing and community development yields a number of insights. First, while long-lived, rich and diverse, this literature is relatively thin and disconnected within the research community and disconnected from practice: innovative models and applications are published in diverse journals, often with non-overlapping disciplinary audiences. Second, the lack of validation of decision models makes the research less attractive to policy-makers (who demand evidence that an innovative program is likely to improve outcomes) or to field managers (who seek guidance regarding routine scheduling and resource allocation decisions). Third, the primary importance of these decision models for practitioners is not their specific prescriptions or methodological innovations, but instead the potential for improved systems and process knowledge that makes better use of training and

expertise. Finally, the current crisis in housing markets provides opportunities for novel applications for acquiring and redeveloping foreclosed housing units, designing more socially and economically sustainable housing construction and community development strategies, and enabling non-profit housing providers to collaborate more effectively.

The remainder of this article is organized as follows. Section I is a review of the literature of decision modeling applications in housing and community development, with an emphasis on those that address issues of affordability and sustainability. Section II synthesizes the previous research and identifies key unanswered questions. Section III contains a research agenda for decision models in housing and community development. Section IV concludes.

I. Survey of Decision Modeling Applications

Our survey of decision modeling applications in affordable housing and sustainable community development is divided into three areas. *Descriptive* research seeks to explain what we observe, specifically, evidence regarding policy initiatives or strategies. *Prescriptive* research supports the identification of a most-preferred policy alternative or set of alternatives. *Decision support systems* are information technology applications that automate the policy analysis and recommendation processes.

Descriptive Research

Descriptive research provides increased understanding of social phenomena that motivate or are influenced by policy initiatives. This research can identify the causes of specific events or observed outcomes, provide evidence regarding the efficacy of policy initiatives or social interventions, and can motivate and justify policy-relevant decision models. Descriptive research for housing and community development encompasses disciplines within the social sciences (economics, policy analysis, urban and regional planning), engineering (civil engineering, industrial and systems engineering) as well as operations research and management science, broadly defined. The literature in these areas is vast, and we make no effort to provide a comprehensive review. In particular, we acknowledge that entire research journals and books are devoted to the study of housing, community development, urban economics and urban affairs. The purpose of this brief review of a portion of this domain is to identify that subset of research

which appears intended to, or can be readily adapted to, support the design of prescriptive models for systems design/redesign. Nearly all of the research discussed in this section describes social phenomena in developed countries, especially the U.S.

We distinguish between descriptive research that is *retrospective* (analysis of particular datasets, or literature reviews) and that which is *prospective* (systems models, sensitivity analyses and simulations). Certain descriptive OR/MS models, such as stochastic processes, are for the purposes of this article classified as 'prescriptive' because they are situated within a research tradition of analysis for system design/redesign.

Retrospective policy-analytic research relevant to housing and community development includes a historical survey of U.S. low-income housing policy culminating in a proposal to fundamentally redesign housing policy to better meet the needs of low- and moderate-income families and communities [23] and a survey of current trends in transit-friendly, mixed-use development and redevelopment of distressed inner-city neighborhoods into mixed-income communities via public-private partnerships [24]. In addition, it is demonstrated in [25] that U.S. consumers still overwhelmingly prefer the traditional suburban model of detached, single-family owner-occupied housing. A research review asserts that presence of low- and moderate-income families in low-density suburbs of Australia that lack certain amenities such as transit access is not in itself evidence of 'locational disadvantage' justifying social interventions; the role of individual social status and locational decisions balancing multiple criteria must be considered as well [26]. An examination of the Canadian rental housing sector since World War II [27] distinguishes markets for housing stock and for rental housing accommodations, describes trends in market outcomes, and identifies social policies that may have produced these outcomes.

There are many applications of housing construction engineering to increase affordability, energy efficiency and structural integrity, and decrease negative environmental impacts. Best practices are presented in [28] for increased use of alternative energy sources and more efficient heating and air conditioning systems. Advanced computer simulation methods and architectural methods to maximize passive solar exposure and minimize building footprints have resulted in significant potential energy savings [29]; similar technologies can be applied to rehabilitation of existing housing in low-income areas [30]. Process engineering methods such as concurrent

engineering [31] and knowledge management [32] can increase the speed and quality of housing construction.

Descriptive models that are more prospective in nature can be classified according to the unit of observation and the level of aggregation. We consider first those models that take a systems view, without explicit consideration of individual housing units, or of individual households. A systems dynamics approach may be used to identify variables to measure environmental sustainability of different development strategies [33]. A critical review of conceptual models and planning frameworks for sustainable affordable housing results in a proposal of a new approach for affordable housing planning that addresses different development phases, is cross-disciplinary and involves multiple experts and stakeholders [19]. Systems dynamics is used to model the social, economic and environmental sustainability of housing and community development [34]. Alternative national-level policies for renovation of the public housing stock are evaluated on the basis of empirically-estimated survivor functions for housing estimated at the city level [35]. A proposed research agenda for social development—including housing—lies at the intersection of systems analysis, sustainable development and MS/OR [36].

Another descriptive modeling approach addresses local, regional or national markets using housing units or households as the basis of analysis. Variations in economic relationships between private developers and public housing managers, and physical configurations of subsidized and market-rate housing are shown to have impacts on regional housing markets [37]. Analysis of production levels of social (subsidized) housing in Ontario is used to determine whether individual planning areas are receiving their “fair share” of social housing [38]. Housing mobility programs, which enable low-income families to choose housing in socially and economically diverse neighborhoods, may decrease regional-level well-being even if they achieve their programmatic goals [39]. Agent-based models (see Article 2.4.1.7, “Agent-based Simulation”) may be used to simulate the spatial impacts of residential location on urban sprawl [40].

Other descriptive models use individual housing units, or families, as the unit of observation, and aggregate these actors to derive characteristics of larger systems. The relationship of an individual housing unit to its environment is used to define measures of environmental sustainability, and thus to measure sustainability impacts of housing-level performance targets

[20]. Observations of individual housing units in a city are inputs to estimated survivor functions based on actuarial methods [41]. A life-cycle analysis of housing using a stocks-and-flows-based model supports the evaluation of the benefits and costs of different housing construction and maintenance practices [42]. Observations of homes advertised for sale can help identify clusters of housing with shared attributes, as well as key physical determinants of housing choice [43]. Surveys and focus groups of residents in affordable housing are used to build and validate a neural network model of residential satisfaction [44].

Much descriptive research relevant to decision models derived from observations of individual units and households has a policy focus on affordable and assisted housing. A method for evaluating the benefits and costs of housing mobility programs is applied to early evaluations of a housing mobility experiment [45]. The American Housing Survey is used to estimate the likelihood of homeownership as a function of a variety of affordable lending policies [46] and to demonstrate that regulations that restrict the supply of newly-constructed, market-rate housing can reduce the size of affordable housing stock [47].

Prescriptive Models

Prescriptive models for housing and community development can be classified as to their temporal and geographical scope and programmatic and spatial specificity. Certain systems models abstract away the details of specific markets or population regions to concentrate on mathematical properties. A systems model of population flows between living arrangements in the wake of a natural disaster is used to formulate multiple partial differential equations whose transient solutions allow evaluation of different public policies [48]. An optimal control model (see Article 3.1.9.11, “Solving Deterministic Optimal Control Problems”) of a generic housing mobility initiative is used to identify stable and unstable long-term equilibria associated with different housing mobility policies [49], [50].

Other models introduce limited spatial as well as programmatic specificity. Optimization of the social surplus associated with stylized land use alternatives, subject to allocation and capacity constraints yields insights regarding the influence of a parameter governing maximization of individual utility or of community utility [51].

Some prescriptive housing models are motivated directly by policy initiatives in defined geographic regions, but place less emphasis on specific spatial characteristics. Formula-based

allocations and a gravity model are used to derive proposed allocations of affordable housing to portions of a metropolitan statistical area [52]. A linear programming model to allocate low-income households to zones in order to minimize total commuting and housing costs can contribute to the design and implementation of a fair housing policy [53]. Multiobjective math optimization is used to generate alternative potential allocations of households using rental vouchers to Census tracts across a county that balance net social benefit and equity (see Article 1.1.1.11, "Solving Multicriteria Problems") [54], [55]; a variation of this model [56] incorporates uncertainty as to the actual locational outcomes of voucher recipients. A multiobjective model for location of project-based subsidized rental housing optimizes social efficiency and equity measures [57]; this model is extended to address affordable housing produced by government and non-governmental organizations [58]. Production levels for affordable housing can be chosen to minimize total costs while accounting for environmental impacts and construction technology requirements [59].

Another stream of research develops regional planning strategies using detailed representations of programs and/or planning units. Urban renewal programs are designed based on the assignment of specific building types, levels and prices to land parcels to optimize net social benefit [60]. A multiobjective land acquisition problem is solved on a grid to optimize compactness and acquisition and development cost as well as land area [61], and proximity to high- and low-amenity communities and compactness [62]. A multicriteria planning problem for "smart growth" using actual, non-uniform land parcels that reflects the perspectives of a government planner, an environmentalist, a conservationist and a land developer yields a nonlinear integer multiobjective math program whose nondominated solutions provide specific guidance to diverse decisionmakers and stakeholders [63].

Tactical planning models for housing construction or redevelopment in specific, localized areas include [60], as well as others where spatial concerns are less important. The Analytic Hierarchy Process (see Article 3.1.8.13, "Analytic Hierarchy Process and Critique") is used to incorporate customer requirements for industrialized housing [31]. Math programs related to production scheduling problems (see Section 4.1.4, "Production Scheduling") are used to design policies for relocating families in public housing communities undergoing renovations to minimize total development time while ensuring that as few families as possible are displaced [64], [65], [66].

Operational models for real estate practice are relatively rare. Multi-attribute utility theory (see Article 3.1.7.19, "Multiattribute Utility Theory") is used to rank applicants to a large commercial development; such a model could easily be applied to residential housing [67]. An application of queueing theory (see Section 2.2.2, "Single-Station Queues: CTMC Models") evaluates the impacts of race-based versus non-race-based tenant assignment policies in public housing on levels of racial segregation and waiting times for available units [68].

Decision Support Systems

Research applications of decision support systems (DSS)(see Section 1.8.1, "Decision Support Systems") for housing and regional planning are numerous (see, e.g. [69]), but those focusing specifically on affordable housing and/or sustainable communities are less common. Computerized applications assist the U.S. Army in forecasting demand and allocating resources for military housing [70], [71]. Using an application for housing mobility planning [54] as the model engine, a spatial DSS (SDSS) can provide strategic guidance to planners and counselors regarding housing mobility policy design [72]. A "proof of concept" DSS for individual housing mobility counseling is developed using the Analytic Hierarchy Process [73]; this work is extended in [74] to develop a Web-accessible prototype SDSS that reflects the needs of housing clients, counselors and landlords. A spatial DSS supports property management and sales, as well as identification of potential properties for purchase [75].

II. Synthesis of Previous Research

There is a strong base of evidence from descriptive models upon which to develop prescriptive models and decision support systems for housing and community development planning, construction and management. While there is no single 'canonical' prescriptive model that captures all elements of housing and community development, a generic multiobjective math programming model for this purpose might be presented as follows. Suppose $\mathbf{X}$ is a vector of decision variables that represent that location, type and number of housing units to be built. Let $B(\mathbf{X})$ represent the net social benefit associated with housing provision strategy $\mathbf{X}$. $B(\cdot)$ can be nonlinear and capture impacts to residents of the housing under consideration, other community residents and taxpayers. Let $E(\mathbf{X})$ represent the environmental impacts of housing provision

strategy **X**. Let F(**X**) represent the perceived fairness, or equity, of the housing provision strategy. Then a social planner would wish to solve

$$\text{Optimize}\{B(\mathbf{X}), E(\mathbf{X}), F(\mathbf{X})\} \quad (1)$$

s.t.

$$C(\mathbf{X}) \leq B \quad (2)$$

$$D_{Min} \leq N(\mathbf{X}) \leq D_{Max} \quad (3)$$

$$\mathbf{X} \in S \quad (4)$$

where objective (1) balances social, environmental and political considerations, constraint (2) ensures that development strategies obey resource limitations and constraint (3) ensures that level of housing provided lies within given estimates of minimum and maximum demand. Constraint (4) ensures that the decision variables obey all relevant spatial and programmatic constraints. This model could address policy design over multiple periods and incorporate uncertainty in housing markets. A large research literature addresses the solution of model (1) – (4): well-known 'classical' approaches include the weighting method and the constraint method [76]; more recent approaches include interactive methods, fuzzy optimization and evolutionary algorithms [77] (see also Article 1.1.1.11, "Solving Multicriteria Problems"). Models such as (1) – (4) could be incorporated into spatial decision support systems.

As discussed above, other modeling approaches, such as agent-based simulation, optimal control and queueing theory could equally well generate alternative housing provision strategies. The practical utility of these planning models is a function of the quality of evidence provided by descriptive research which generates insight into the social, environmental and political impacts of housing and community development policies.

Research in housing and community development described in the previous section and summarized in model (1) – (4) above faces significant limitations. Prescriptive planning models which are partial-equilibrium, deterministic and single-period in nature may be insufficiently flexible to address the diversity of problems typical of housing and community development. There does not appear to be a "theory" of affordable housing or sustainable community development that can be adapted to diverse regions, economies or housing types. There are few examples of explicit modeling of stakeholder values to generate decision models that achieve

social goals shared across stakeholders (see e.g. section 3.1.3, "Normative Structuring of Decision Problems"). Few models attempt to jointly and explicitly address social welfare and equity (see e.g. articles 3.1.15.3, "Assessing Social Welfare and Utility Functions from Survey Data" and 3.1.15.5, "Fairness and Equity in Social Decision Analysis") and environmental impacts. There is little research on models linking strategic, tactical and operational concerns that correspond to the process of policy planning, design, implementation and evaluation, though [47], [53] and [70], and [72] address, separately, strategic, tactical and operational aspects of housing mobility programs. With some exceptions (e.g. [66], [71]), most models have neither been applied in the field nor rigorously evaluated according to best practices and specific real-world data.

These limitations motivate many questions that future research might address. Some of these include: How can descriptive models for policy analysis address multiple policy alternatives simultaneously? What types of prescriptive planning models are most appropriate for housing and community development? When are spatial versus aspatial models most appropriate? What barriers prevent consistent use of prescriptive models? How can prescriptive models explicitly address the "geography of opportunity"? How can speculative, forward-looking models be validated? How can modelers trade off model realism and detail against tractability?

III. Research Agenda

We discuss a number of promising extensions to the decision modeling research described in this article.

Descriptive Models

It was argued above that a key element of prescriptive models for affordable housing and community development is the formulation and measurement of social welfare. Despite innovative models for measuring regional impacts of housing mobility programs that incorporate scale economies and variations across neighborhood types [39] and estimates of individual-level impacts of housing mobility programs [45], no similar work has addressed similar impacts associated with housing redevelopment programs. In addition, there is no research known to this

author that evaluates the full range of social benefits and costs of housing and community development initiatives.

It would be of interest to formulate multi-state dynamic models of affordable housing and community development programs that incorporate multiple transitions over space, class and time associated with policy interventions such as particular assisted housing programs but also normal class and household mobility; there has been initial limited effort in this area [78]. Another approach could extend current research on agent-based models for residential location such as [40] to affordable housing and community development policy design. Here, agents could be individual families who participate in a housing mobility or housing redevelopment initiative.

The field of construction engineering and architecture also can also benefit from research that applies current technologies to the design of sustainable housing units and communities. Agent based modeling and cellular automata are applied to the design of virtual cities [79]. These designs are based on simulation models for energy-efficient residential housing based using data from daily activities of residents [80].

Prescriptive Models

Housing providers and community development experts can choose from many affordable housing planning and management tools [81]. A multi-criteria decision analysis could assist organizations in choosing the methods that are best-suited to their technical capabilities, funding streams and service area characteristics. Another application might adapt methods from human-computer interaction research to evaluate the benefits perceived by housing and community development practitioners of decision models.

U.S. hurricanes Katrina and Rita in 2005, as well as the Indian Ocean earthquake/tsunami of 2004 are examples of natural disasters that can result in immense human and physical losses. While the urban planning profession has performed admirably in developing redevelopment strategies for New Orleans in the wake of hurricane Katrina (see, e.g. [82]), there are opportunities for OR/MS to provide prescriptive planning models for urban redevelopment in the wake of natural disasters (and see related articles 4.6.3.1 “Disaster Preparedness” and 4.6.3.2, “Evacuation Planning”). [83] is an initial effort in this direction, but much more research is needed.

Affordable housing providers face intense competition for increasingly limited development resources. A regional decision model could provide guidance regarding alternative strategies for collaboration across jurisdictional boundaries, service categories and client populations.

Of great interest in the current foreclosure crisis is the development of strategies to select foreclosed housing units for purchase, redevelopment and resale or ongoing management. A multi-objective discrete math programming model for strategy design in foreclosed housing acquisition is developed and applied to a small suburban municipality [84]. Current extensions derived from observations of a community practitioner include solving the tactical problem of choosing specific foreclosed units to acquire that addresses risk, strategic nature of physical location and social impacts, and incorporating uncertainty and risk into the strategic multiobjective acquisition model.

Decision Support Systems

Information technology-enabled decision support is ubiquitous. However, practitioners in affordable housing and community development, especially those serving distressed communities, have limited access to IT applications that might help them make better decisions about services to use, or provide a means for them to participate in the policy design. Spatial decision support systems for affordable housing and community development could be developed that are easy for inexperienced users to master, that use detailed housing market and community-level data, that allow users to identify and rank decision alternatives with a variety of methods, and that facilitate collaboration between multiple stakeholders. Preliminary analysis [85] has described the prospects of a professional-quality SDSS that might fulfill the promise of the prototype [74]. DSS might also be used to facilitate the design of energy-efficient residential units using engineering and architectural best practices. Finally, a recent graduate student service learning project has developed a decision support system for management of services for the homeless [86, p. 3].

IV. Conclusion

In this article we have reviewed models for housing and community development, especially those that to address issues of affordability and sustainability. The research literature in this area

is large, diverse and long-lived, but with substantial opportunities to perform research across disciplines, develop a general theory of prescriptive modeling and decision support and generate real-world applications. A number of promising extensions may both shed light on dynamics of real-world behaviors of actors in the housing and community development process and provide specific guidance to allow them to more fully enjoy the benefits of affordable housing and sustainable communities.

Acknowledgements

This research was funded in part by the National Science Foundation Faculty Early Career Development (CAREER) Program, "CAREER: Public-Sector Decision Modeling for Facility Location and Service Delivery." Thanks to Felicia Sullivan (University of Massachusetts Boston) and Philip Akol, Changmi Jung, Jeannie Kim and Vincent Chiou (Carnegie Mellon University) for their research assistance.

References

[1] Joint Center for Housing Studies of Harvard University. The State of the Nation's Housing 2006. 2006. World Wide Web: http://www.jchs.harvard.edu/publications/markets/son2006/son2006.pdf. Accessed June 25, 2009.

[2] Rohe, WM, McCarthy, G, Van Zandt. S. "The social benefits and costs of homeownership: a critical assessment of the research." 2001. Joint Center for Housing Studies, Harvard University, Cambridge, MA. Working Paper LIHO 01.12.

[3] U.S. Department of Housing and Urban Development. Affordable Housing Needs 2005: A Report to Congress. Office of Policy Development and Research. 2007. World Wide Web: http://www.huduser.org/intercept.asp?loc=/Publications/pdf/AffHsgNeeds.pdf. Accessed June 5, 2009.

[4] Millennial Housing Commission. Meeting Our Nation's Housing Challenges: A Report of the Bipartisan Millennial Housing Commission Appointed by the Congress of the United

States. 2002. World Wide Web: http://govinfo.library.unt.edu/mhc/MHCReport.pdf. Accessed June 5, 2009.

[5] NAACP and National Association of Home Builders. Building on a Dream. 2006. Web: http://www.nahb.org/fileUpload_details.aspx?contentTypeID=7&contentID=2858. Accessed June 5, 2009.

[6] National Housing Conference. A Heavy Load: The Combined Housing and Transportation Burdens of Working Families. Prepared by B.J. Lippman. 2006. Center for Housing Policy, Washington, D.C. Web: http://www.nhc.org/pdf/pub_heavy_load_10_06.pdf. Accessed June 5, 2009.

[7] National Housing Conference. Housing & Transportation Cost Trade-offs and Burdens of Working Households in 28 Metros. Prepared by P.M. Haas, C. Makarewicz, A. Benedict (Center for Neighborhood Technology) and T.W. Sanchez and C.J. Dawkins (Virginia Tech). 2006. Center for Housing Policy, Washington, D.C. Web: http://www.nhc.org/pdf/chp-pub-hl06-cnt-report.pdf. Accessed June 5, 2009.

[8] National Housing Conference. Making Do: How Working Families in Seven U.S. Metropolitan Areas Trade Off Housing Costs and Commuting Times. Prepared by R. Cevero, K. Chapple, J. Landis and M. Wachs (Institute for Transportation Studies, University of California, Berkeley). 2006. Center for Housing Policy, Washington, D.C. Web: http://www.nhc.org/pdf/chp-pub-hl06-berkeley-report.pdf. Accessed June 5, 2009.

[9] PolicyLink and Community Development Partnerships Network. Shared Prosperity, Stronger Regions: An Agenda for Rebuilding America's Older Core Cities. Prepared by R.K. Fox, S. Treuhaft and R. Douglass. 2005. World Wide Web: http://www.policylink.org/atf/cf/%7B97c6d565-bb43-406d-a6d5-eca3bbf35af0%7D/SHAREDPROSPERITY-CORECITES-FINAL.PDF. Accessed June 5, 2009.

[10] Goetz, EG. Clearing the Way: Deconcentrating the Poor in Urban America. 2003. Urban Institute Press, Washington, D.C.

[11] de Souza Briggs, X. Politics and Policy: Changing the Geography of Opportunity. Pp. 310 – 341 in de Souza Briggs, X, ed. The Geography of Opportunity: Race and Housing Choice in Metropolitan America. 2005. Brookings Institution Press, Washington, D.C.

[12] National Bureau of Economic Research. "Determination of the December 2007 peak in economic activity." Business Cycle Dating Committee, December 11, 2008. 2008. World Wide Web: http://www.nber.org/cycles/dec2008.html. Accessed June 6, 2009.

[13] Joint Center for Housing Studies of Harvard University. The State of the Nation's Housing 2008. 2008. World Wide Web: http://www.jchs.harvard.edu/publications/markets/son2008/son2008.pdf. Accessed June 5, 2009.

[14] Baker, D, Rosnick, D. "The impact of the housing crash on family wealth." Center for Economic and Policy Research 2008. World Wide Web: http://www.cepr.net/documents/publications/wealth_2008_07.pdf. Accessed June 6, 2009.

[15] Atlas, J, Dreier, P. 2008. "Stemming the red tide." Shelterforce 2008 Spring; 8 – 15.

[16] Joint Center for Housing Studies of Harvard University. America's Rental Housing: The Key to a Balanced National Policy. 2008. World Wide Web: http://www.jchs.harvard.edu/publications/rental/rh08_americas_rental_housing/rh08_americas_rental_housing.pdf. Accessed June 5, 2009.

[17] Olsen, EO. Housing Programs for Low-Income Households. Pp 365 – 441 in RA Moffitt, ed. Means-Tested Transfer Programs in the United States. 2003. The University of Chicago Press, Chicago.

[18] Urban Land Institute. Housing for Moderate-Income Households in the European Union and the United States. Prepared by John McIlwain. 2003. Washington, D.C.

[19] Salama, AM, Alshuwaikhat, HM. A transdisciplinary approach for a comprehensive understanding of sustainable affordable housing. Glob Built Env Rev 2006; 5(3): 35 – 50. World Wide Web: https://www.edgehill.ac.uk/gber/pdf/vol5/issue3/Article%204.pdf. Accessed June 5, 2009.

[20] Priemus, H. How to make housing sustainable? The Dutch experience. Environ Plann B Plann Des 2005; 32(1): 5 – 19.

[21] Glaeser, EL. "Places, people, policies: an agenda for America's urban poor." Harvard Magazine 2000; 103(2). World Wide Web: http://www.harvardmagazine.com/on-line/1100126.html. Accessed June 5, 2009.

[22] Pendall, R, Nelson, AC, Dawkins, CJ, Knaap, GJ. Connecting Smart Growth, Housing Affordability, and Racial Equality. Pp. 219 – 246 in X. de Souza Briggs, ed. The Geography of Opportunity: Race and Housing Choice in Metropolitan America. 2005. Brookings Institution Press, Washington, D.C.

[23] von Hoffman, A. High ambitions: the past and future of American low-income housing policy. Hous Policy Debate 1996; 7(3): 423 – 446.

[24] Bohl, CC. New urbanism and the city: potential applications and implications for distressed inner-city neighborhoods. Hous Policy Debate 2000; 11(4): 761 – 801.

[25] Myers, D, Gearin, E. Current preferences and future demand for denser residential environments. Hous Policy Debate 2001; 12(4): 633 – 659.

[26] Maher, C. Residential mobility, locational disadvantage and spatial inequality in Australian cities. Urban Pol Res 1994; 12(3): 185 – 191.

[27] Miron, J.R. Private rental housing: the Canadian experience. Urban Stud 1995; 32(3): 579 – 604.

[28] U.S. Department of Energy. Building America Field Project: Results for the Consortium for Advanced Residential Buildings (CARB), January to October 2001. National Renewable Energy Laboratory. Prepared by Steven Winter Associates, Inc. 2001. World Wide Web: http://www.nrel.gov/docs/fy03osti/31380.pdf. Accessed June 5, 2009.

[29] U.S. Department of Energy. Design, Construction, and Performance of the Grand Canyon House. National Renewable Energy Laboratory. Prepared by J.D. Balcomb, C.E. Hancock and G. Barker. 1999. World Wide Web: http://www.nrel.gov/docs/fy99osti/24767.pdf. Accessed June 5, 2009.

[30] Katrakis, JT, Knight, PA, Cavallo JD. "Energy-efficient rehabilitation of multifamily buildings in the Midwest". Argonne National Laboratory, Decision and Information Sciences Division. 1994. World Wide Web: http://www.osti.gov/bridge/servlets/purl/10186292-Xtn9vf/webviewable/10186292.pdf. Accessed June 5, 2009.

[31] Armacost, RL, Paul, J, Mullens, MA, Swart WW. An AHP framework for prioritizing customer requirements in QFD: an industrialized housing application. IIE Trans. 1994; 26(4): 72 – 80.

[32] Ibrahim, R, Nissen, M. Emerging Technology to Model Dynamic Knowledge Creation and Flow among Construction Industry Stakeholders during the Critical Feasibility-Entitlements Phase. Pp. 1 – 14 in I. Flood, ed. Information Technology 2003: Towards a Vision for Information Technology in Civil Engineering. 2004. American Society of Civil Engineers, Reston, VA. World Wide Web: http://cedb.asce.org/cgi/WWWdisplay.cgi?0305909. Accessed June 5, 2009.

[33] Kelly, KL. A systems approach to identifying decisive information for sustainable development. Eur J Oper Res 1998; 109: 452 – 464.

[34] Hjorth, P, Bagheri, A. Navigating towards sustainable development: a systems dynamics approach. Futures 2006; 38(1): 4 – 92.

[35] Gleeson, ME. Renovation of public housing: suggestions from a simple model. Manage Sci 1992; 38(5): 655 – 666.

[36] Midgley, G, Reynolds, M. Systems/operational research and sustainable development: towards a new agenda. Sus Dev 2004; 12(1): 56 – 64.

[37] Tiesdell, S. Integrating affordable housing within market-rate developments: the design dimension. Environ Plann B Plann Des2004; 31: 195 – 212.

[38] Skelton, I. Planning under welfare pluralism: social housing targets and allocations in Ontario, Canada. Geoforum 1997; 28(1): 79 - 89.

[39] Galster, GC. Consequences from the redistribution of urban poverty during the 1990s: a cautionary tale. Econ Dev Q 2005; 19(2): 119 – 125.

[40] Brown, DG, Robinson, DT. Effects of heterogeneity in residential preferences on an agent-based model of urban sprawl. Ecol and Soc 2006. 11(1), 22 pages. World Wide Web: http://www.ecologyandsociety.org/vol11/iss1/art46/ES-2006-1749.pdf. Accessed June 8, 2009.

[41] Gleeson, ME. Estimating housing mortality from loss records. Environ Plan A 1985; 17: 647 – 659.

[42] Johnstone, IM. Development of a model to estimate the benefit-cost ratio performance of housing. Const Manage Econ 2004; 22: 607 – 617.

[43] Day, L. Choosing a house: the effect of cost constraints on single-family house design and construction. Environ Plann B Plann Des 1995; 22: 603 – 622.

[44] Paris, DE, Kangari, R. Multifamily affordable housing: residential satisfaction. J Perform Constr Facil 2005; 19(2): 138 – 145.

[45] Johnson, MP, Ladd, HF, Ludwig, J. The benefits and costs of residential-mobility programs for the poor. Hous Stud 2002; 17(1): 125 – 138.

[46] Quercia, RG, McCarthy, GW, Wachter, SM. The impacts of affordable lending efforts on homeownership rates. J Hous Econ 2003; 12(1): 29 – 59.

[47] Tsuriel Somerville, C, Mayer, CJ. Government regulation and changes in the affordable housing stock. FBRNY Econ Policy Rev 2003; 9(2): 45 – 62.

[48] Nikolopoulos, CV, Tzanetis, DE. A model for housing allocation of a homeless population due to a natural disaster. Nonlinear Anal Real World Appl 2003; 4(4): 561 - 579.

[49] Caulkins, JP, Feichtinger, G, Grass, D, Johnson, MP, Tragler, G, Yegorov Y. Placing the poor while keeping the rich in their place: separating strategies for optimally managing residential mobility and assimilation. Demogr Res 2005; 13(1): 1 – 34.

[50] Caulkins, JP, Feichtinger, G, Johnson, MP, Tragler, G, Yegorov, Y. Skiba thresholds in a model of controlled migration. J Econ Behav Organ 2005; 57(4): 490 – 508.

[51] Brotchie, JF. A new approach to urban modelling. Manage Sci 1978; 24(16): 1753 – 1758.

[52] Frech, GM, Thyagarajan, S. Housing allocation model for low-income and moderate income households in Albany Schenectady Troy SMSA. J Env Sys 1975; 5(1): 59 - 77.

[53] Kim, TJ. Alternative model for fair share allocation of lower-income housing. Socioecon Plann Sci 1979; 13(2): 113 - 116.

[54] Johnson, MP, Hurter, AP. Decision support for a housing relocation program using a multi-objective optimization model. Manage Sci 2000; 46(12): 1569 – 1584.

[55] Johnson, MP. Single-period location models for subsidized housing: tenant-based subsidies. Ann Oper Res 2003; 123: 105 – 124.

[56] Johnson, MP. Tenant-based subsidized housing location planning under uncertainty. Socioecon Plann Sci 2001; 35(3): 149-173.

[57] Johnson, MP. Single-period location models for subsidized housing: project-based subsidies. Socioecon Plann Sci 2006; 40(4): 249 – 274.

[58] Johnson, MP. Planning models for affordable housing development. Environ Plann B Plann Des 2007; 34(3): 501 – 523.

[59] Tiwari, P, Parikh, J, Sharma, V. Performance evaluation of cost-effective buildings – a cost, emissions and employment pint of view. Build Env 1996; 31(1): 75 – 90.

[60] Atkins, RS, Krokosky, EM. Optimum housing allocation model for urban areas. Journal of the Urban Planning & Development Division 1971; 97(1): 41 – 53.

[61] Wright, J, ReVelle, C, Cohon, J. A multiobjective integer programming model for the land acquisition problem. Reg Sci Urban Econ 1983; 13: 31 – 53.

[62] Gilbert, KC, Holmes, DD, Rosenthal, RE. A multiobjective discrete optimization model for land allocation. Manage Sci 1985; 31(12): 1509 – 1522.

[63] Gabriel, SA, Faria, JA, Moglen GE. A multiobjective optimization approach to smart growth in land development. Socioecon Plann Sci 2006; 40: 212 – 248.

[64] Kaplan, EH. Relocation models for public housing redevelopment programs. Environ Plann B Plann Des 1986; 13: 5 – 19.

[65] Kaplan, EH, Amir, A. A fast feasibility test for relocation problems. Eur J Oper Res 1987; 35(2): 201 – 206.

[66] Kaplan, EH, Berman, O. OR hits the heights: relocation planning at the Orient Heights housing project. Interfaces 1988; 18(6): 14 – 22.

[67] Yau, C, Davis, T. Using multi-criteria analysis for tenant selection. Decis Support Syst 1994; 12: 233 – 244.

[68] Kaplan, EH. Analyzing tenant assignment policies. Manage Sci 1987; 33(3): 395 – 408.

[69] Timmermans, H. (Ed.) Decision Support Systems in Urban Planning. 1997. E & FN SPON, London.

[70] Forgionne, GA. HANS: A decision support system for military housing managers. Interfaces 1991; 21(6): 37 – 51.

[71] Forgionne, GA, Frager YS. The US Army relies on decision support systems in allocating housing resources. Interfaces 1998; 28(2): 72 – 79.

[72] Johnson, MP. A spatial decision support system prototype for housing mobility program planning. J Geogr Sys 2001; 3(1): 49 – 67.

[73] Johnson, MP. Decision support for family relocation decisions under the section 8 housing assistance program using GIS and the analytic hierarchy process. J Hous Res 2002; 12(2): 277 – 306.

[74] Johnson, MP. Spatial decision support for assisted housing mobility counseling. Decis Support Syst 2005; 41(1): 296 – 312.

[75] Zeng, TQ, Zhou, Q. Optimal decision making using GIS: a prototype of a real estate graphical information system (REGIS). Int J Geogr Inf Sci 2001; 15(4): 207-321.

[76] Cohon, JL. Multiobjective Programming and Planning. 1978. Academic Press, New York.

[77] Ehrgott, M, Gandibleux, X. (Eds.) Multiple Criteria Optimization: State of the Art Annotated Bibliographic Surveys. 2002. Secaucus, NJ.

[78] Johnson, MP, Caulkins JP. "Can housing mobility programs make a long-term impact on the lives of poor families and the health of middle-class communities: a policy simulation." Heinz School Working Paper Series 2005-33. 2006.

[79] Chiou, YS, Davison, C. "Virtual metropolis for smart growth policy analysis: an agent-based/cellular automata dual-layered complex system model". EcoCity World Summit 2008, San Francisco.

[80] Chiou, YS, Carley KM. "Characterizing U.S. single-family detached house through social network analysis". Unpublished working paper. .

[81] Washington Area Housing Partnership. Toolkit for Affordable Housing Development. 2005. Washington, D.C. World Wide Web: http://www.wahpdc.org/Toolkit_for_Affordable_Housing_Dev_2-17-06.pdf. Accessed June 8, 2009.

[82] Hartman, C, Squires, GD. There Is No Such Thing as a Natural Disaster: Race, Class, and Hurricane Katrina. 2006. Routledge, New York.

[83] Jung, C, Johnson, MP, Williams, JC. "Mathematical models for reconstruction planning in urban areas." Heinz School Working Paper Series 2007-10. 2007.

[84] Johnson, MP, Turcotte, D, Sullivan FM. "What foreclosed homes should a municipality purchase to stabilize vulnerable neighborhoods?"; under review at Netw Spat Econ 2009.

[85] Johnson, MP. "Can a spatial decision support system improve low-income service delivery? Analysis of tools and requirements for a computer-assisted mobility counseling system." Heinz School Working Paper Series 2005-32. 2005.

[86] Nesmith, R. "Working out for the best: Panel discussion highlights students presenting Computing For Good projects." The Whistle 34(32). World Wide Web: www.whistle.gatech.edu/archives/09/dec/14/dec14.pdf. Accessed January 3, 2010.

Further Reading

Boardman, AE, Greenberg, DH, Vining, AR, Weimer DL. Cost-Benefit Analysis: Concepts and Practice, Third Edition. 2006. Pearson Education, Inc., Upper Saddle River, NJ.

Eiselt, HA, Sandblom, C-L. Decision Analysis, Location Models , and Scheduling Problems. 2004. Springer-Verlag, Berlin.

Fotheringham, AS, O'Kelly, ME. Spatial Interaction Models: Formulations and Applications. 1989. Kluwer Academic Publishers. Dordrecht.

Green, RK, Malpezzi, S. A Primer on U.S. Housing Markets and Housing Policy. 2003. The Urban Institute Press, Washington, D.C.

Hannon, B, Ruth, M. Dynamic Modeling, Second Edition. 2001. Springer-Verlag, New York.

Johnson, MP, Smilowitz, K. Community-Based Operations Research. Pp 102 – 123 in T. Klastorin, ed. Tutorials in Operations Research 2007. 2007. Institute for Operations Research and the Management Sciences, Hanover, MD.

Keeney, RL. Value-Focused Thinking: A Path to Creative Decisionmaking. 1992. Harvard University Press, Cambridge, MA.

Larson, RC, Odoni, AR. Urban Operations Research. 1981. Prentice-Hall, New Jersey. World Wide Web: http://web.mit.edu/urban_or_book/www/book/. Accessed June 26, 2009.

Malczewski, J. GIS and Multicriteria Decision Analysis. 1999. John Wiley & Sons, Inc., New York.

Marianov, V. and Serra, D. Location Problems in the Public Sector. Pp 119 – 150 in Z. Drezner and H. W. Hamacher, eds. Facility Location: Applications and Theory. 2004. Springer-Verlag, Berlin.

Pollock, SM, Rothkopf, MH, Barnett, A. (Eds.) Handbooks in Operations Research and Management Science, Vol. 6: Operations Research and the Public Sector. 1994. North-Holland, Amsterdam.