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Research Advances in Behavioral, Economic and Health Geography Inspired by Gerard Rushton

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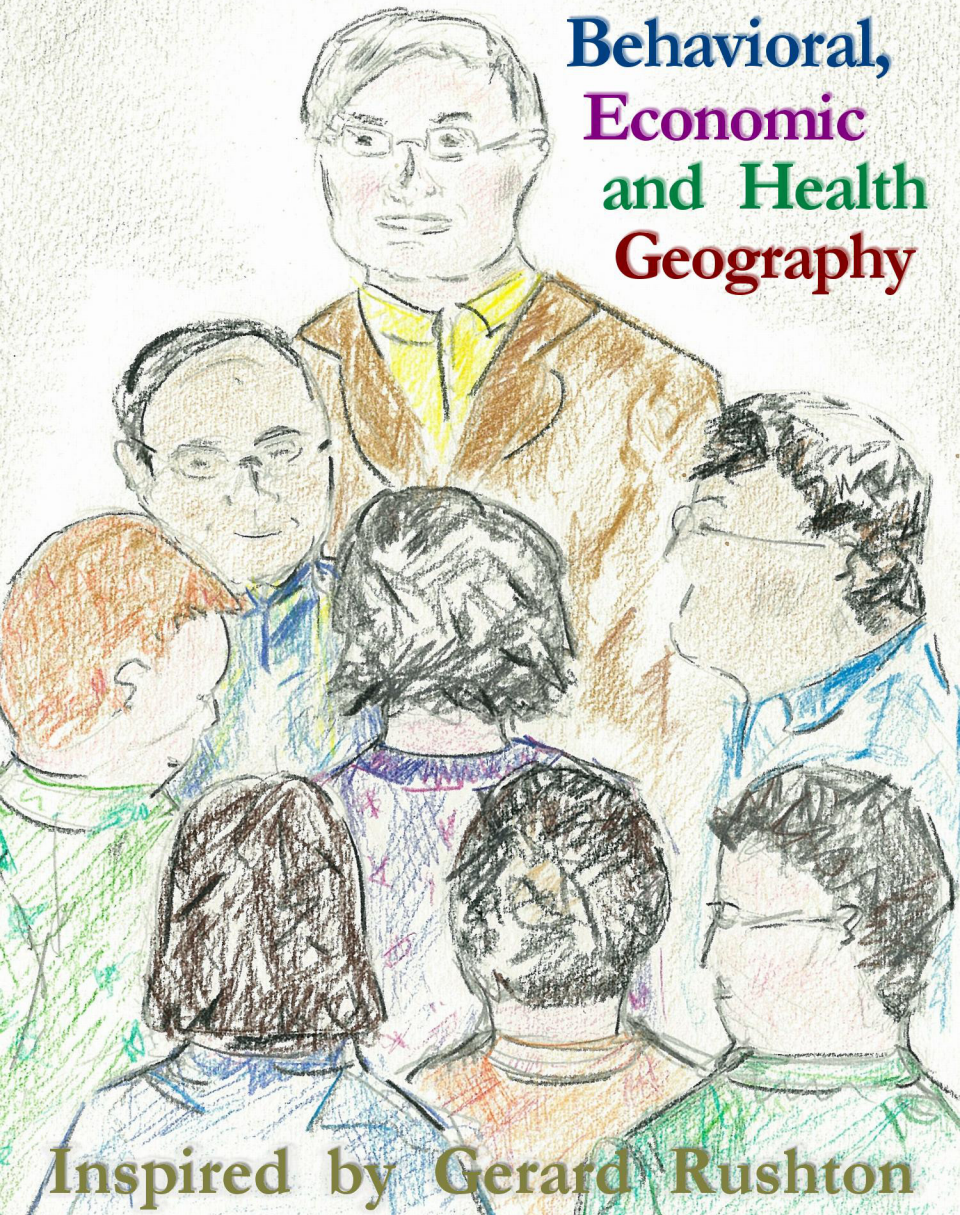
Research Advances in Behavioral, Economic and Health Geography



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Preface

This is a festschrift including nine scientific papers and six abstracts of papers written by Dr. Gerard Rushton or his former graduate students and colleagues to celebrate his retirement from teaching at the University of Iowa, Iowa City, Iowa, USA. The festschrift begins with Rushton's own review of his research advances in Behavioral Geography, Economic Geography and Health Geography that coincide with three recurring phases of his academic career during 45 years of teaching at the University of Iowa. Following this, each paper by a former student or colleague reviews the special personal and academic contributions of Rushton to him or her in one of those research areas. Each paper then proceeds to review the author's (or authors') contributions to scientific theory and empirical analysis that he or she (or they) has(ve) subsequently advanced or evolved from Rushton's original contributions. These papers are scientific contributions of interest to an academic readership, as opposed to personal or anecdotal recollections.

The seeds of this festschrift were in the much earlier comments of two of Rushton's former students in the same cohort as me, Sally McLafferty and Avijit Ghosh. I remembered their comments when Carolyn and Gerry Rushton announced in their annual Christmas card that Gerry was formally retiring from teaching in 2013. I subsequently compiled a list of Gerry's twenty former graduate students at the University of Iowa with their help as well as that of Dave Bennett and Cynthia Hernandez, respectively the chair and administrator of the Department of Geographical and Sustainability Sciences at the University of Iowa.

Seven of 13 contacted former students then presented draft papers in a one-day symposium at the University of Iowa in June 2013, with Gerry presenting his own concluding

paper. Eight former students and colleagues, including three who had not participated in the one-day symposium, subsequently presented draft papers in two special sessions during the 2014 annual meetings of the Association of American Geographers in Tampa, Florida, with Gerry again presenting a concluding paper. In total, eight authors or groups of authors submitted papers in this festschrift in addition to Gerry. The nine chapters are augmented with a tenth chapter of the abstracts of papers of six remaining former students who either presented during the one-day symposium, or would have presented if they had been able to attend it or the two special sessions.

Nine papers and six abstracts in this festschrift from a one-day symposium and two special sessions at a conference represent a sample of those in three research areas of Behavioral Geography, Economic Geography and Health Geography. Gerry Rushton in the first introductory chapter reviews his scholarly contributions in each of the three research areas during 50 years of professional life. Within these scholarly contributions are the inspirations for the research of former students and colleagues who are authors of the subsequent chapters.

Gordon Ewing is the author of the first of three chapters on research in Behavioral Geography written by Gerry's former students or colleagues. Gordon traces his original critical analyses of calibrated parameters for spatial interaction models, and his progression into discrete choice modelling of individuals' environmental and travel behaviors from Rushton's earlier research into consumer spatial behavior. Similarly, Tom Bell in the next chapter has returned with a different perspective than his original quantitative one to the interpretation of modern and historical central places providing goods and services to dispersed consumers. Somewhat differently, Alan Phipps critically reviews one of

Rushton's earliest published articles and its antecedents as bases for subsequent research into residents' decisions to move home.

In the first of two chapters on research in Economic Geography, Mike Goodchild compliments Rushton for contributing to his evolution from a graduate student studying karst geomorphology to a protagonist of geographic information science in the face of humanist critiques. Tom Eagle then demonstrates the application of Rushton's decision support system with spatial statistical analysis and GIS for predicting retail sales at existing and new stores of a client in the private sector.

In the first of three chapters on research in Health Geography, Kirsten Beyer critically analyzes Rushton's pioneering work in disease mapping for realizing positive impacts of lessons from Dr. John Snow, such as, about geographic scale in spatial patterns of disease, and translation of research findings into interventions to improve health. Ellen Cromley in the next chapter refines Rushton's analysis of individual-level geocoded health data for demonstrating the colocation quotient as a measure of spatial association among categories in a population who have global and local patterns of successful and unsuccessful aging. Sara McLafferty, Avijit Ghosh and Jamie Fishman in the final paper also apply Rushton's locational analysis research as a framework for an empirical analysis of inequalities in spatial accessibility to primary care physicians in the Chicago region, including those who are international medical graduates.

In sum, this festschrift's nine chapters written by former graduate students or colleagues of Gerry Rushton were inspired by his research during one of three recurring phases that I have referred to as Behavioral Geography, Economic Geography, or Health Geography. Even these students and colleagues who read Gerry Rushton's introductory chapter in

this festschrift may learn of not only the breadth and depth of the productive advances in his research, but also his motivations for these advances during a very long period of time. Reciprocally, Gerry and they may read the subsequent chapters and abstracts to discover how the research of those who were not their contemporaries has frequently advanced in unpredicted directions, just as Gerry advanced as a researcher from one phase to the next in his professional life.

Indeed, Gerry Rushton's former students and colleagues have similarly to him sustained their ability for advancing geographical research, especially from a scientific perspective, over a period of more than 40 years for some. This sustained interest in and ability for independent research may thus be the gift of Rushton to his former students and colleagues and, vice versa, the reciprocation of them to him. This respectful reciprocity would for sure explain why so many of them including Gerry were eager to present a paper in a one-day symposium and two special sessions. For all of this, I would like to give thanks to Gerry Rushton on your behalf – and on his behalf, to give thanks to all of you.

Alan G Phipps,
Harrow, Ontario, Canada
July 2016

I. Introduction

Gerard Rushton in the first chapter reviews the scholarly contributions of his research in Behavioral, Economic and Health Geography during 50 years of professional life. Within these scholarly contributions are the inspirations for the research of former students and colleagues who are authors of the subsequent chapters.

Chapter 1

A Brief Review of my Scholarly Contributions in Behavioral, Economic and Health Geography

Gerard Rushton

1.1 Introduction

I wrote this chapter on the occasion of my retirement from the University of Iowa. This juncture in my life seemed a good time to briefly review my scholarly contributions in the fields of Behavioral, Economic and Health geography during five phases of my professional life so far.

Space does not permit me to comment on the many things I learned from students, faculty colleagues, and many others with whom I worked. However, I would like to clarify Goodchild's comment in his chapter that Rushton's thinking was intuitive, not mathematical, and that I worried a problem to a solution [1]. All very true. The worry, I think, was to see the problem expressed in a way that satisfied me. The thought that always pushed my thinking was whether I agreed with the problem as others saw it, which was frequently where the problem lay.

For example, I recall a three-day meeting of specialists in location theory in the early 1970s. Michael Dacey, a prolific author of papers on central place theory at the time, stripped off the dust jacket of Walter Christaller's book [2] while standing before his audience. He waved the graphics of hexagons nestled one within the other saying, "I tell my students this is all you need to know about this theory". A

few minutes later, it was my turn to speak. Waving the same book, I said:

> "I tell my students these get all the attention when people write about this theory but, inside, you will find little discussion of this graphic. Christaller writes here about the behaviors of people as consumers and their behaviors as suppliers of goods and services; and he writes about how towns and service centers and their functions arise from the mutually adaptive behaviors of the two".

I had only recently reached the conclusion that Dacey and his many followers perceived a different problem of what about central place theory should be researched and what needed to be discovered.

Similarly, during a subsequent phase with several students when I was researching methods to solve heuristic location-allocation problems, I was less interested in finding better algorithms than in finding algorithms that solved for the kind of behaviors that consumers and suppliers engaged in. Later when I was researching spatial patterns of infant mortality and birth defects, I was less interested in assessing national patterns of mortality and morbidity rates, and more focused on finding robust patterns of rates at the clearest small-area level. In all three cases, I think what distinguished my approach was that I was defining the problem differently from others.

When I read the research of my former students and colleagues, I can now discern their further innovations in definition of a research problem. The remainder of this chapter hopefully provides a foundation for the research advances of my former students and colleagues in the nine chapters that follow in this book.

1.2 Behavioral Geography 1964-1970: Analysis of Spatial Choice and Revealed Space Preferences

My publications during a Behavioral Geography phase refined models of consumer spatial behavior to predict the places that people living in typical rural environments such as in Iowa would select to satisfy their needs for goods and services. This research began with an English translation of Christaller's 1933 dissertation that had become available in 1961 with a microfilm of Baskin's dissertation [2]. I studied this microfilm as a class project in an urban geography class with Professor James Lindberg at the University of Iowa. I was interested that Christaller payed very little attention in his book to the spatial-hierarchical arrangement of central places that he had deduced was a characteristic of the central places of Southern Germany. Instead, he focused his discussion on the respective spatial behaviors of people there in their roles as consumers and producers of basic services.

The literature of the early 1960s either focused on the geometric characteristics of central place systems or on the empirical study of activities in central place systems. I, however, focused on the behavior of consumers and how Christaller's central places systems emerged from changes in the spatial behavior of consumers and the reactions of producers of services to these behaviors.

At this time, I was a research assistant in the Bureau of Business and Economic Research (BBER) at the University of Iowa. The BBER was noted for market area analyses in which teams of students in the College of Business delineated the areas served by towns based on interviews with consumers. I contacted the director and suggested that these market area boundaries were surely predictable based on secondary data about towns, their contents, and their relative locations; see also Tom Bell's chapter in this book [3]. In my

opinion, the field surveys were inefficient and performed poorly, as very small local samples were ineffective for estimating the boundaries in question.

I ultimately hypothesized the use of spatial search algorithms and multi-dimensional choice functions to reveal how individuals evaluated potential places, and chose one place while constrained by personal, social and other factors. These revealed space preference functions in a spatial context ordered the alternative places from which a person could choose. Several areas of technical progress were needed to implement these ideas; see also Gordon Ewing's chapter [4]. Spatial searches of the places surrounding people required that persons and places be geocoded and that efficient search algorithms be constructed; the results of such searches needed to be captured and attributes of searched places needed to be linked; places chosen by individuals from their discrete alternatives needed to be ranked; and most challenging of all, a choice function needed to be found that would reconstruct the ordering of the alternatives given the personal characteristics of the individuals; see also Alan Phipps's chapter [5].

Several early publications were co-authored with Reginald Golledge and William Clark, with whom I worked after my stint at the BBER. Dr. Ron Boyce hired us to analyze some of the sample data on the household consumer behavior of the dispersed Iowa population.

An early incentive for my development of GIS was that most analyses depended on developing a geographic base file consisting of location coordinates of not only all towns and townships in Iowa, but also those of a random sample of farm and non-farm rural residents. With such a geospatial database first developed in 1963, I was able to write search algorithms showing not only the place chosen by the sample residents but also alternative places which they could have chosen but did

not choose. These publications and this methodology became widely adopted in subsequent research on spatial choice in the emerging field of GIS. This work culminated in my paper [6] that 15 years later received Classic status.

1.3 Health Geography 1971-1981: Spatial Patterns of Facility Locations and the Optimal Locations of Facilities in Iowa, Nigeria and India

A theme of publications with colleagues at the University of Iowa, and in institutions around the world during my first Health Geography phase, was that network-based location-allocation algorithms could be used with geospatial databases to measure the spatial accessibility of people in a system of service facilities. Another theme was the utilization of these algorithms to identify new locations for improving access to primary health centers, schools, marketing facilities, branch banks and other rural services. In India, in particular, the World Bank had begun to invest in improving the marketing facilities and the planning infrastructure for such services.

My research was assisted by collaborations in two externally-supported applied research projects. The first involved five short-term visits between 1971 and 1974 as a consultant to the Ford Foundation in New Delhi, India. The Ford Foundation was advising the Indian Ministry of Agriculture on a large project to bring scientific planning principles and methods of spatial analysis to the planning of rural services in India. The objective was support for access to essential services needed to advance the green revolution that had started in India in 1968.

The second project was with the Regional Medical Program (RMP) in Iowa, which was one of a national system of such programs designed to bring the benefits of advances in medicine to areas of the U.S. that were not part of the

medical revolution. In the Iowa RMP, I led a project on planning access to primary health and dental services in the state of Iowa.

In both projects I developed large geospatial databases that included finely geocoded measures of demand for health services with spatially geocoded measures of existing health resources. In both cases my colleagues and I developed heuristic location-allocation models and implemented them with the large spatial databases even though constrained by limited computer capabilities of the 1970s in Iowa and New Delhi. My interest in regional development theory and regional planning projects matured during this period (e.g., [7]).

1.4 Economic Geography 1981-1995: Decision Support Systems for Efficient Decision-making in Locating Public Facilities

The theme of my publications during a first Economic Geography phase was the development of measures of the cost to the public of suboptimal locations of facilities [8]. My research in Iowa and India in the 1970s had convinced me of the frequent occurrence of better locations than chosen ones for a wide range of activities. A better location was defined as a new location that had 'better' measures on all of the attributes that the decision makers themselves had stated were important. In practice, better locations were measured by location-allocation models applied to geospatial data of local areas. These algorithms had objective functions operationalizing decision criteria that decision-makers claimed were their objectives.

With two grants from the National Science Foundation, and with colleagues Michael McNulty from the University of Iowa, Vinod K. Tewari from the Indian Institute of

Management, Bangalore, Bola Ayeni from the University of Ibadan, we interviewed decision-makers in India and Nigeria who had been responsible for recent location decisions about health centers and public schools. Our spatial simulations confirmed alternative locations to those actually chosen would have performed better according to the multiple criteria expressed by the decision-makers. Also during this period, I visited projects being implemented by USAID in an attempt to improve rural access to services in developing countries, including the Philippines, Jordan, Israel, and Bolivia.

Microcomputers were becoming available, and so the efficiency of location decision-making could clearly be enhanced by taking microcomputers into the field and interacting with local decision-makers. Questions and answers could be asked and answered in real time with community involvement in the interaction. I did this in projects in India, Nigeria, Iowa and Australia. It was during this period, for example, that Michael Goodchild joined me in India where he began to program micro computer code to measure access to services in rural study areas.

I further developed these real-time computer-interactive spatial analyses in the presence of decision-makers for enhancing the quality of their location decisions with solicited community input. For example, my colleague Rex Honey and our students in the geography department at Iowa utilized computer-interactive spatial analyses for conveying both past and projected spatial demographics to decision-makers in the field of public education. The contexts were school enrollment projections for Iowa schools, the location of new schools or the closure of old schools, and the spatial reorganization of the administration of school districts.

We used a more efficient heuristic for solving large p-median problems [9] and kernel ratio-estimation functions [10] for calculating spatially-varying rates of student

enrollment growth or decline. After geocoding individual student data, enrollment changes over flexibly-defined geographic catchment areas were monitored for projecting future enrollments for small areas and providing spatial decision support for the public where conflicts occurred; see also Tom Eagle's chapter [11]. These efforts continued with applications in legislative redistricting in South Africa [12].

1.5 Health Geography 1996-2002: Geographic Information Systems and Public Health

I renewed my primary research interest in Health Geography after I realized the field of public health had many substantive problems for which GIS methods and tools were useful (e.g., [13]; see also chapters by Ellen Cromley [14], and Sara McLafferty, Avijit Ghosh and Jamie Fishman [15]). I had answered a call from a university colleague in Pediatrics who asked whether it was true that State Department of Health records could be automatically mapped and made available to the press. My colleague was concerned about a journalist's report in The Des Moines Register of hotspots in one area of Des Moines, IA, with high rates of death from congenital diseases allegedly caused by pollution levels in surrounding areas.

Following some publications in this field as well as some committee assignments with public health groups, I subsequently received a grant with colleague Marc Armstrong from the U.S. Department of Education to develop modules to educate the public health workforce in the use of GIS in public health research and practice. Together with Bob Aangeenbrug and others, I was invited by the National Cancer Institute (NCI) to advise it about implementing the Long Island Breast Cancer Project.

1.6 Health Geography 2003-present: Geocoding Cancer Data and Mapping Small Area Incidence, Mortality, and Staging Cancer Patterns

Another theme in my renewed research in Health Geography was the refinement of kernel density methods to display spatial patterns of cancer using typical disease registry data. This research developed after serving on a committee of the NCI charged with developing a plan for cancer surveillance for the millennial decade. My students and I embraced the recommendation for cancer data to be routinely geocoded to a fine geographical level for mapping small-area cancer rates [16].

Recent research has focused on principles for mapping chronic diseases, such as cancer; see also Kirsten Beyer's chapter [17]. My innovation has been that, instead of starting the disease mapping process with a traditional data matrix with areas in the rows and rates of disease in the columns, the process begins with very small area data and then aggregates information for areas with approximately the same size populations at risk. The disease rate estimates consequently have approximately constant variability in errors of estimate. This spatial aggregation estimate therefore relieves a map from its principal failure in the contemporary literature of having estimates of disease rates with different levels of statistical error across the map.

1.7 The Present and Future

My crossing the Atlantic Ocean for five days on The Queen Mary, and taking the train from New York City to Iowa City in September, 1961, changed my life in so many ways. I often think of Harold "Mac" McCarty who welcomed me to the University of Iowa as a Fulbright Scholar from the

University of Wales in Aberystwyth. Mac inculcated the spirit of scientific scholarship among faculty and students at the university at a time when so little of the scholarship in geography was done in this spirit.

My plan was to stay one year in America, but that year grew to two more years as a graduate student at the University of Iowa; three years as an assistant professor at McMaster University, Canada; two years at Michigan State University; and a return to Iowa that lasted 45 years with a two-year interim at San Diego State University.

I now have joined the ranks of Professor Emeritus and, after three years of feeling my way to a different daily routine, I am beginning to find the rewards of this new life. I still check the week's schedule ahead but there are far fewer items on it. The academic literature continues and I continue to follow and enjoy much of it. I retired with four unfinished student dissertations in progress. The number is now two. That, too, is part of my present workload. I also have a weekly phone call with two former students and I am currently enjoying finishing our second paper for publication since retirement. I accept most invitations to review the scholarship of others for their periodic professional evaluations. Taking most of my time for continued professional work are the services I do on several National Institute of Health (NIH) review groups.

I smiled recently after receiving an e-mail from NIH, stating that since I had served on at least six research proposal review groups in the past eighteen months, I am now allowed to submit proposals to many of their research solicitations at any time rather than follow their deadlines for bi-annual submissions! These reviews each take at least one week of work and frequently a day or two in Washington, DC. But I enjoy the challenge of evaluating proposals for research and discussing them with multi-disciplinary review groups.

So, as I now watch from a distance the University of Iowa's Geography Department, I support and pay some attention to the Gerard Rushton Academic Excellence Fund, and I thank the Geography Alumni for their generous gift that set up this fund. I hope that it will contribute to a never-ending effort to enrich the discipline through the work of faculty and students while helping to maintain a community of excellence on the prairie.

Farther afield, Carolyn and I acquired a vacation home with swimming pool in Punta Gorda, FL, shortly after my retirement. After installing a solar heater for the pool, I enjoy at least two swims a day with water temperature never below 80 degrees F at any time of year. It has beautiful sunset views of "the Meadows" and, especially in summer, it is nice to swim under the stars. Both our sons and their families visit there at least twice a year and our five-year-old granddaughter says, "I'm going to live in Florida when I grow up!"

References

[1] M. F. Goodchild, "Gerard Rushton and Quantitative Human Geography", in Research Advances in Behavioral, Economic and Health Geography Inspired by Gerard Rushton, A. G. Phipps, Ed. Windsor, ON: University of Windsor, pp. 59-69, 2016.

[2] W. Christaller, Central Places in Southern Germany, C.W. Baskin, translator. Englewood Cliffs, NJ: Prentice-Hall, 1966.

[3] T. L. Bell, "Gerry Rushton, Central Place Theory and me: The influence of a geographic visionary on one of his students", in Research Advances in Behavioral, Economic and Health Geography Inspired by Gerard Rushton, A. G. Phipps, Ed. Windsor, ON: University of Windsor, pp. 31-39, 2016.

[4] G. O. Ewing, "A life of preference: Evolution of research from spatial interaction modelling to discrete choice modelling", in Research Advances in Behavioral, Economic and Health Geography Inspired by Gerard Rushton, A. G. Phipps, Ed. Windsor, ON: University of Windsor, pp. 19-29, 2016.

[5] A. G. Phipps, "Studying human spatial decision-making and its environmental effects, beginning with an article by Gerard Rushton", in Research Advances in Behavioral, Economic and Health Geography Inspired by Gerard Rushton, A. G. Phipps, Ed. Windsor, ON: University of Windsor, pp. 41-56, 2016.

[6] G. Rushton, "Analysis of spatial behavior by revealed space preference," Annals of the Association of American Geographers, vol. 59, no. 2, pp. 391-400, 1969.

[7] H. B. Fisher and G. Rushton, "Spatial efficiency of service locations and the regional development process," Papers, Regional Science Association, vol. 42, pp. 83-97, 1979.

[8] G. Rushton, "The Roepke Lecture in Economic Geography: Location theory, location-allocation models, and service development planning in the Third World," Economic Geography, vol. 54, no. 2, pp. 97-120, 1988.

[9] P. J. Densham and G. Rushton, "Strategies for solving large location-allocation problems by heuristic methods," Environment and Planning A, vol. 24, pp. 289-304, 1992.

[10] G. Rushton, M. P. Armstrong and P. Lolonis, "Small area student enrollment projections based on a modifiable spatial filter," Socio-Economic Planning Sciences, vol. 29, no. 3, pp. 169-185, 1995.

[11] T. C. Eagle, "Integrating a hierarchical Bayes Gravity-like model into a retail chain's IT system", in Research Advances in Behavioral, Economic and Health Geography Inspired by Gerard Rushton, A. G. Phipps,

Ed. Windsor, ON: University of Windsor, pp. 71-81, 2016.

[12] J. D. Barkan, P. J. Densham and G. Rushton, "Space matters: Designing better electoral systems for emerging democracies," American Journal of Political Science, vol. 50, no. 4, pp. 926-939, 2006.

[13] G. Rushton. and P. Lolonis, "Exploratory spatial analysis of birth defect rates in an urban population," Statistics in Medicine 15, 717-726. 1996.

[14] E. K. Cromley, "Spatial analysis of successful aging in older adults based on objective and subjective measures," in Research Advances in Behavioral, Economic and Health Geography Inspired by Gerard Rushton, A. G. Phipps, Ed. Windsor, ON: University of Windsor, pp. 99-109, 2016.

[15] S. McLafferty, A. Ghosh and J. Fishman, "Do international medical graduates (IMGs) improve spatial access to physicians? Rushton's locational analysis framework in practice," in Research Advances in Behavioral, Economic and Health Geography Inspired by Gerard Rushton, A. G. Phipps, Ed. Windsor, ON: University of Windsor, pp. 111-124, 2016.

[16] G. Rushton, M.P. Armstrong, J. Gittler, B. Greene, C. Pavlik, M. West and D. Zimmerman, Eds. Geocoding Health Data: The Use of Geographic Codes in Cancer Prevention and Control, Research and Practice, Boca Raton, FL, CRC Press/Taylor and Francis, 2008.

[17] K. Beyer, "The lessons of Snow: A call for translational health geography," in Research Advances in Behavioral, Economic and Health Geography Inspired by Gerard Rushton, A. G. Phipps, Ed. Windsor, ON: University of Windsor, pp. 85-97, 2016.

II. Behavioral Geography

In the first chapter of three on research in Behavioral Geography, Gordon Ewing traces his original critical analyses of calibrated parameters for spatial interaction models, and his progression into discrete choice modelling of individuals' environmental and travel behaviors from Rushton's earlier research into consumer spatial behavior. Similarly, Tom Bell in the next chapter has returned with a different perspective than his original quantitative one to the interpretation of modern and historical central places providing goods and services to dispersed consumers. Somewhat differently, Alan Phipps critically reviews one of Rushton's earliest published articles and its antecedents as bases for his subsequent research into residents' decisions to move home.

Chapter 2

A Life of Preference: Evolution of Research from Spatial Interaction Modelling to Discrete Choice Modelling

Gordon O. Ewing

2.1 Introduction

One of the challenges for space preference research identified by Dr. Gerard Rushton was to discover spatial choice rules that are independent of the local spatial configuration of alternative destinations. During the 1960s and even the early 1970s, it was common for those analyzing spatial behavior of shoppers, for example, to fit a linear regression model equivalent to an unconstrained gravity model. Each observation of the dependent variable in this model was the trip volume from a given origin to a given destination, and the independent variables described only characteristics of the given destination and its distance from that origin. Such a model effectively assumes that the spatial arrangement of other destinations has no bearing on the value of the dependent variable.

The challenge of this misspecification eventually turned Rushton to the work of mathematical psychologists studying choice behavior [1]-[3]. The method of paired comparisons was at the heart of his key paper on space preferences [4]. The other key feature of this paper was the use of a Kruskal's [5] nonmetric multidimensional scaling program to derive an interval scale of preferences for location types, based on

paired comparisons' proportions inferred from consumers' choices of one location type over others.

It was the rise of mainframe computers in the early 1960s that enabled mathematical psychologists to write iterative nonmetric multidimensional scaling algorithms for the scaling of individuals' perceptions. But, in addition to using programs written by them, we were writing our own, which for me at least, meant sitting for hours in noisy labs filled with IBM keypunch machines and preparing decks of punch cards to submit to the operator of the university's mainframe computer. Every so often at Michigan State University a notice would alert that a limited number of users could use the computer overnight. As soon as we heard of this we would sign up for these nights and often be there into the wee hours getting very fast turnaround on our jobs. All of these would run in a couple of seconds on a modern laptop.

After my 'exchange' year at MSU, I returned to McMaster University in the summer of 1968 and completed my dissertation in early 1971 [6], effectively under Gerry's supervision, though officially under that of the professor who replaced him. This made me Gerry's first doctoral student to graduate.

2.2 Spatial and Environmental Choice Modelling

Despite Rushton's [4] key paper, leading journals continued to accept papers that estimated parameters in spatial interaction models that were biased by the geometry of interaction opportunities. This prompted me to offer the editor a criticism of a paper published in *Economic Geography* in 1973. It concluded by saying that aside from Rushton's paper, there were few papers in geography explicitly addressing the problem of estimating parameters in spatial choice models [7]. The article prompted two useful papers by Cesario [8] [9],

the latter in response to Michael Goodchild's comments to the editor about the former. Goodchild during the 1970s was both writing about spatial choice modeling and supervising a doctoral thesis [10] on the topic at Western University, formerly the University of Western Ontario.

Meanwhile, in 1974 I was struggling with how to estimate multiple parameters for destination attributes in probabilistic spatial choice models. This is effectively the probabilistic component of Wilson's [11] production-constrained gravity model in his family of spatial interaction models.

The approach I took beginning in 1973 to estimate weights for multiple destination attributes was a compromise that involved not estimating a distance deterrence effect. The specific question addressed was what factors other than distance affected the attractiveness of U.S. states to interstate migrants. I computed the relative proportion of U.S. interstate migrants moving to one state rather than another equidistant state, thereby eliminating the role of distance in the choice. Also, in order to factor out the effect of state population, migration numbers were standardized by origin and destination state population. Using 1960 U.S. Census data this provided sufficient paired comparison proportions to use a nonmetric MDS algorithm [12] to derive a scale of state attractiveness, independent of state population and distance. The regional structure that emerged was very clear with the warmer western states at the top of the scale and Appalachian states at the bottom [13]. Two-thirds of the variance in attractiveness scores was explained by two climatic factors, one pollution factor, state urbanization and density, and the non-white population percentage.

At the same time as the above study, a similar one was being conducted on revealed and stated preferences for 23 Vermont ski resorts, using license plate data at these resorts

for revealed preferences and interviews with skiers for the stated preferences [14]. The method used to infer revealed preferences from license plate data was taken from the aforementioned dissertation of Goodchild's student [10]. Both papers offered insights into ways of extracting information about the antecedents of locational preferences. But neither satisfactorily encompassed both the effect of distance and destination attributes in a single model such as a production-constrained gravity model.

2.3 General Linear Modelling

My foray into recreational travel modeling had resulted in an invitation to meet a British geographer who was visiting Parks Canada, a department in the Canadian federal government that was coordinating the Canadian Outdoor Recreation Demand Study. That meeting led me to spend half of a sabbatical leave at the Tourism and Recreation Research Unit attached to the Geography Department at Edinburgh University. I had agreed to design a household survey of day-trip travel behavior in the summer of 1976. It was at the Unit that I began a long and fruitful collaboration with its mathematical statistician, Mike Baxter. He was intrigued by gravity models in their various guises.

Working with a production-constrained gravity model, we initially used our own Newton-Raphson optimization algorithm to estimate a set of destination attractiveness parameters and two parameters in a distance deterrence function. Baxter then wrote an in-house piece showing that the estimation problem was much more easily solved by applying a multinomial extension of the logit regression model [15].

This was the beginning of my introduction to generalized linear models (GLMs) and how they could be used to estimate

the parameters of the production-constrained gravity model among others. The necessary statistical software package had been developed by the Royal Statistical Society's Working Party on Statistical Computing in 1974 and publicised the following year as GLIM, Generalized Linear Interactive Modeling [16]. "GLIM was notable for being the first package capable of fitting a wide range of generalized linear models in a unified framework, and for encouraging an interactive, iterative approach to statistical modeling" [17].

Using GLIM, it was easy to show that the simple gravity model, the doubly-constrained entropy-maximizing and the production-constrained trip distribution models were all simple variants of a general equation. Indeed, by treating origin-destination trip volumes as a Poisson random variable, we were able to show that different mathematical forms of production-constrained trip distribution models yielded very similar or identical maximum likelihood estimates of parameters when fitted to data [18].

2.4 Discrete Choice Modelling

By the early 1980s there were still grounds for modeling aggregate spatial interaction data where, for example, variety seeking behavior was likely, as in the case of tourism and recreation travel. Nevertheless, there was a growing interest in discrete choice modeling as it related to many choice situations. Within geography and beyond, one of the leaders in a branch of this field concerned with stated preference and choice was another of Rushton's doctoral graduates, Jordan Louviere.

About 1984 I began co-supervising an Austrian graduate student at McGill University, Wolfgang Haider, who was interested in tourist destination choice behavior in the Caribbean. I was familiar with Louviere's work on discrete

choice experiments and the fractional factorial design of choice sets to present to subjects. With invaluable assistance from Louviere and his research colleague, Don Anderson, a statistician, Haider provided them with ten attributes, each with three levels, for which they provided him with an appropriate fractional design from which to construct choice sets [19].

Haider went on to do ground-breaking research while working as a research scientist for the Ontario Ministry of Environment at the Centre of Northern Forest Ecosystem Research in Thunder Bay, Ontario. Using discrete choice experiments with input from Louviere, Anderson and others, he presented potential recreational fishers with choice sets describing imaginary remote fly-in wilderness destinations in Northwest Ontario. The orthogonal designs included images of lakes that had been digitally manipulated to reflect different levels of landscape alteration due to forestry activity [20]. He subsequently continued his research at Simon Fraser University where he is professor in the School of Resource and Environmental Management.

By the second half of the 1980s I had decided to reorient my research on spatial choice behavior into fields with a more explicit 'environmental' focus. I mounted a survey of Montrealers' reported levels of recycling behavior. This was in the early 1990s when domestic curbside recycling was in its infancy in Montreal. For each of five classes of recyclables (paper, cardboard, glass, cans and hard plastics), a binomial logit regression of the choice to be a high or low recycler revealed the decision was influenced by the egoistic factor (perceived inconvenience of recycling that class of object), and belief that household members wanted the respondent to recycle it. In contrast, altruism as measured by the strength of their belief that recycling helped the environment, did not

play a role. Personal utility and the moral influence of valued others were the deciding factors [21].

In 1993 the opportunity arose to conduct a substantial piece of stated discrete choice research on car-borne commuters in Montreal, funded by an Environment Canada initiative that supported academic research on economic instruments for environmental sustainability. The challenge was to estimate the likely effectiveness of policies aimed at reducing solo-driver commuting in conventional cars in the metropolitan area. There were two sets of customized discrete choice experiments administered to 900 respondents: One was on how choice might be affected by manipulating the relative commuting cost or travel time of driving alone compared to ridesharing and using transit. The other more complex experiment was designed to discover the relative demand for less polluting and zero-emission vehicles compared to conventional ones, depending not only on differences in their performance and market cost characteristics, but also in travel cost and travel time characteristics that could be manipulated by public policy. A detailed report of the findings [22] was followed by papers on results of the first experiment [23] and the second [24] [25].

2.5 Conclusion

In 2003 I began supervising my last doctoral student, Zachary Patterson. He was prompted by environmental considerations to investigate what might influence shippers to move freight between major cities by a less polluting and congesting mode than tractor-trailer. Specifically, using a contextual stated preference survey he wanted to discover the influence of defined variables and factors on their choice between road-only and intermodal transport. The latter included specialized scheduled freight trains with rapid-

loading flatbed rail wagons designed to piggyback truck trailers. With funding support to his co-supervisors from Transport Canada and the Railway Association of Canada, Patterson was able to design a web-based stated preference survey based on a fractional factorial design to discover what factors influence the modal choices of various types of shippers in the Windsor-Quebec City Corridor [26].

Following the successful defense of his dissertation in 2006, he spent two years in Switzerland working on integrated transportation land-use modeling at Michel Bierlaire's Transport and Mobility Laboratory, Ecole polytechnique fédérale de Lausanne. After a further two years as a modeling specialist with Montreal's Metropolitan Transport Agency, he won a prestigious federally-funded Canada Research Chair, Tier 2. Seeing a talented researcher like Zak Patterson continue the study of preference and choice in socially important areas of spatial and environmental analysis is further testament to Gerry Rushton's far-reaching geographical and intellectual legacy. In addition to his own long and illustrious career, he has been responsible for igniting intellectual curiosity and inquiry both directly in his own graduate students and through them in further generations of scholars.

References

[1] C. H. Coombs, A Theory of Data. New York, NY: Wiley, 1964.

[2] W. S. Torgerson, Theory and Methods of Scaling. New York, NY: Wiley, 1958.

[3] H. A. David, The Method of Paired Comparisons. London, UK: Griffin, 1963.

[4] G. Rushton, "The scaling of locational preferences," in Behavioral Problems in Geography: A Symposium, K. R.

Cox and R. G. Golledge, Eds. Evanston, Ill : Northwestern University, Department of Geography, Research Paper No. 17, 1969, pp. 197-227.

[5] J. B. Kruskal, "Nonmetric multidimensional scaling: A numerical method," Psychometrika, vol. 29, pp. 1-27, 1964.

[6] G. Ewing, An Analysis of Consumer Space Preferences using the Method of Paired Comparisons. Unpublished Ph.D. dissertation, McMaster University, Hamilton, ON, 1971.

[7] G. Ewing, "Gravity and linear regression models: A cautionary note," Economic Geography, vol. 50, pp. 83-88, 1974.

[8] F. J. Cesario, "Linear and nonlinear regression models of spatial interaction," Economic Geography, vol. 51, pp. 69-77, 1975.

[9] F. J. Cesario, "Alternative models for spatial choice," Economic Geography, vol. 52, pp. 363-73, 1976.

[10] J. H. C. Ross, A Measure of Site Attraction. Unpublished Ph.D. dissertation, The University of Western Ontario, London, ON, 1972.

[11] A. G. Wilson, Papers in Urban and Regional Analysis. London, UK: Pion, 1972.

[12] J. C. Lingoes, The Guttman-Lingoes nonmetric program series. Ann Arbor, MI: Mathesis Press, 1973.

[13] G. Ewing, "Environmental and spatial preferences of interstate migrants in the U.S.A.," in Spatial Choice and Spatial Behavior: Geographic Essays on the Analysis of Preferences and Perceptions, R. G. Golledge and G. Rushton, Eds. Columbus, OH: Ohio State University Press, 1976, pp. 249-270.

[14] G. Ewing and T. Kulka, "Revealed and stated preference analysis of ski resort attractiveness," Leisure Sciences, vol. 2, pp. 249-75, 1979.

[15] G. Ewing, "The interpretation and estimation of parameters in constrained and unconstrained trip distribution models," Economic Geography, vol. 54, pp. 264-73, 1978.

[16] J. A. Nelder, "Announcement by the working party on statistical computing: GLIM (Generalized Linear Interactive Modelling Program)," Journal of the Royal Statistical Society. Series C (Applied Statistics), vol. 24, pp. 259-261, 1975.

[17] M. D. Aitkin, B. F. Anderson and J. Hinde, Statistical Modelling in GLIM. Oxford, UK: Oxford University Press, 1989.

[18] M. J. Baxter and G. Ewing, "Calibration of production-constrained trip distribution models and the effect of intervening opportunities," Journal of Regional Science, vol. 19, pp. 319-330, 1979.

[19] W. Haider and G. Ewing, "A model of tourist choices of hypothetical Caribbean destinations," Leisure Sciences, vol. 12, pp. 33-47, 1990.

[20] G. Ewing and W. Haider, "Estimating what affects tourist destination choice," in Consumer Behavior in Travel and Tourism, A. Pizam, and Y. Mansfeld, Eds. Binghamton, NY: Haworth Press, 1999, pp. 35-58.

[21] G. Ewing, "Altruistic, egoistic and normative effects on curbside recycling," Environment and Behavior, vol. 33, pp. 733-764, 2001

[22] G. Ewing, "The role of user charges in reducing automobile air pollution in Canada," Final report to Environment Canada (Economic Instruments Initiative - University Research Program), 1996.

[23] Z. Patterson, G. Ewing and M. Haider, "Gender-based analysis of work trip mode choice of commuters in suburban Montreal, Canada, with stated preference data," Transportation Research Record: Journal of the

Transportation Research Board, no. 1924, Management and Public Policy, pp. 85-93, 2005.

[24] G. Ewing and E. Sarigollu, "Car fuel-type choice under travel demand management and economic incentives," Transportation Research D: Transport and Environment, vol. 3, no. 6, pp. 429-444, 1999.

[25] G. Ewing and E. Sarigollu, "Assessing consumer preferences for clean-fuel vehicles: a discrete choice experiment," Journal of Public Policy and Marketing, vol. 19, no. 1, pp. 106-118, 2000.

[26] Z. Patterson, G. Ewing and M. Haider, "The potential for premium-intermodal services to reduce freight CO2 emissions in the Quebec City - Windsor Corridor," Transportation Research D: Transport and Environment, vol. 13, no. 1, pp. 1-9, 2008.

Chapter 3

Gerard Rushton, Central Place Theory and Me: The Influence of a Geographic Visionary on One of His Students

Thomas L. Bell

3.1 The Predoctoral Stage: My Experience as Gerard Rushton's Student and Research Assistant

I was Dr. Gerard Rushton's first doctoral advisee at the University of Iowa, although he had advised several doctoral students at McMaster University and Michigan State University before his return to his doctoral alma mater. I was also lucky to take a class in intermediate economic geography from him as an undergraduate student at Iowa, and to see first-hand how he presented complex ideas in location theory, especially central place theory.

I nevertheless was uncertain about what aspect of central place theory I should pursue when I was trying to formulate a defensible dissertation proposal. After reading so much of the extant central place theory literature, I began to hypothesize that the underlying organizing principles of Walter Christaller and August Lösch were quite different. Perhaps real world central place systems were a hybrid amalgam of the hierarchical principle of Christaller [1] and the area-serving principle of Lösch [2]. But how was I going to test that hypothesis?

My breakthrough lay in the applied literature of rural sociology, especially the work of Edward Hassinger [3] at the

University of Wisconsin at Madison. He explored the use of Guttman scaling to delineate a hierarchy of central place functions in a manner different from that of Berry and Garrison's duplication ratio method [4]-[6]. I decided to expand on Hassinger's method in my doctoral research.

3.2 Rushton's Influence on My Doctoral Research

I thought that Guttman scaling could not only be used to delimit hierarchical marginal goods in a central place system. I thought it also could be used to differentiate goods that did not conform to hierarchical principles of Walter Christaller [1] from those that conformed more to the area-serving principles discussed by August Lösch [2]. Another graduate student in the Department of Geography helped me to write computer code that would allow Guttman scaling to be applied to much larger matrices of places and their functional content than was then possible with available statistical programs [7] [8].

Rushton however posed a new research question that started me on a six-month intensive research effort. Namely, is the order of exit of goods out of a central place system the mirror image of the order of entry into that same commercial economy? What was needed to provide the answer were longitudinal data. So, my dissertation suddenly involved a lot of time spent in the Iowa State Historical Society's archive of old city directories and telephone directories. I recorded at two-year intervals for a decade the entries and exits of every store, and the goods they carried, in a seven-county area centered on Des Moines for about fifty places that ranged in size from tiny hamlets to Des Moines itself.

3.3 Integrating Classical Location Theory with Advances in Behavioral Geography

The state of Iowa has always been the classic central place testing ground since the environment is relatively uniform, there are few barriers to movement, and the main *raison d'etre* of most settlements is to provide a surrounding rural farm and non-farm population with goods and services [9] [10]. However, my attempt to model dynamic entrepreneurial response that would parallel and complement Rushton's contributions to an understanding of consumer spatial behavior was not as successful as either of us would have liked. I simply could not demonstrate that order of exit was the mirror image of order of entry based on threshold level of economic support.

Although I could not successfully integrate the interaction between consumer and entrepreneur, I obtained my doctoral degree [11] and published results of my preference structure delimitation of market areas in textbook chapters [12, 13]. The method I had used to identify hierarchical marginal goods appeared in an article that I jointly published [14].

3.4 An Extension and a New Collaboration: Central Place Principles in Archaeology

I shifted away from central place theory research when I took a teaching position at the University of Tennessee in 1971. I was, however, pleased one day in 1973 when my department head brought to my attention an article that applied central place theory to Classic Era (approximately 600 AD to 900 AD) settlements in the Maya lowland of present-day Mexico, Guatemala, Belize and Honduras [15].

I was intrigued for two reasons, as (1) finally another discipline was borrowing location theory from geography rather than the other way around; and (2) the application appeared wrongheaded. The settlements supposedly conformed to the geometric principles of a hexagonal lattice in an extremely uneven environment with major hills, sink holes and other karst features. Even spacing of settlements in such an undulating environment, in my opinion, denied rather than supported central place principles, and indicated that other factors such as defensive or religious/ceremonial considerations were at work in settlement location.

Some of my archaeological applications of location modeling owe much to Dr. Karl Butzer, as he had amassed the best data available on Egyptian settlement patterns along the Nile and its tributaries during the time of the Ramessid pharaohs (1300-1100 BC). He had a graduate student, Ms. Barbara Kaufmann, working on analysis of these data for her Master's thesis. He had read some of my contributions to the archaeological literature with my new collaborator at the University of Tennessee, Dr. Richard ('Rick') L. Church [16] [17].

3.5 Central Place Theory: The Transition from Archaeological Applications to Location-Allocation Modeling

Rick and I gladly helped Barbara with her Egyptian settlement research by suggesting she test the hypothesis that political control of the populace was very centralized under the Ramessid pharaohs. The pharaohs' administrative centers for governing their 23 political districts called nomes seemed to have been very efficiently located. To test a hypothesis of bureaucratic efficiency, a maximal covering solution was

developed that allocated the 128 unearthed settlements among the 22 nome capitals.

That efficient solution was then compared with (1) the solution actually used by the pharaohs; and (2) solutions in which 23 settlements are simply drawn at random 5,000 times from among the 128 choices in order to generate a frequency distribution of random solutions. The pharaohs' solution was much closer to the optimal one than to any measure of central tendency generated by the random selections [18] [19].

3.6 The Serendipity of Complementarity: Central Places Thirty Years On

The most important influence in my life and on my more recent research has been my wife, Dr. Margaret M. Gripshover, who would describe herself as a cultural/historical geographer. One research effort that we undertook together was to examine the retail changes within the central places that I had examined for my dissertation thirty years earlier. I told her I actually had not visited them for my dissertation, relying instead on data derived from city directories and telephone directories. She was appalled, and insisted that we actually go to those same places in central Iowa and observe what had happened to their commercial structures.

Our examination was informed by the results of consumer spatial behavior findings we had completed as investigators on a grant funded by the US Environmental Protection Agency [20] [21]. Despite the rise of the big-box retailers, the urge to shop at locally owned stores for ethical and other reasons appears to be stronger than ever [22]. Sometimes labeled as neolocalism, this desire is manifest in such disparate ways as local food movements and resurgence

of farmers' markets and craft breweries, in conjunction with avoidance of corporate chain operations [23].

3.7 Conclusion: An Only Superficial Parting of the Ways

Rushton's subsequent research from my perspective may have focused more on health geography and the application of GIS-based technologies for identifying disease clusters and the optimal locations of treatment clinics. My recent research, on the other hand, has focused more on aspects of American popular culture, especially rock music capitalizing on my undergraduate major and minor in the humanities (history major and minor in English literature) and my son's experience with the music industry as a musician in both unsuccessful and successful bands. I even invited my graphic artist daughter into some of my music research [24]. In the end, however, I always tried to emulate Rushton's practical dicta in my seemingly disparate research topics: 1) I read and consumed voraciously the bodies of literature pertaining to any new research subject or application area; 2) I sought an identifiable spatial perspective to all research questions; and 3) I always speculated about how the subject of attention might be produced, consumed or distributed in a more geographically efficient, equitable and/or sustainable manner.

References

[1] W. Christaller, Central Places in Southern Germany, C.W. Baskin, translator. Englewood Cliffs, NJ: Prentice-Hall, 1966.

[2] A. Lösch, The Economics of Location, W. H. Woglom and W. F. Stolper, translators. New Haven, CT: Yale University Press, 1954.

[3] E. Hassinger, "The relationship of retail-service patterns to trade center population change," Rural Sociology, vol. 22, pp. 235-240, 1957.

[4] B. J. L. Berry and W. L. Garrison, "Functional bases of the central place hierarchy," Economic Geography, vol. 34, pp. 145-154, 1958.

[5] B. J. L. Berry and W. L. Garrison, "A note on central place theory and the range of a good," Economic Geography, vol. 34, pp. 107-120, 1958.

[6] B. J. L. Berry and W. L. Garrison, "Recent developments of central place theory," Papers and Proceedings of the Regional Science Association, vol. 4, pp. 107-120, 1958.

[7] T. L. Bell, "An analysis of the functional content of central places using scalogram analysis," Proceedings of the Association of American Geographers, vol. 2, p. 191, 1971.

[8] T. L. Bell and P. L. Frankland, "A method for analyzing a class of related problems in the patterning of central place activities," Southeastern Geographer, vol. 12, pp. 30-40, 1973.

[9] G. Rushton, "Preference and choice in different environments," Proceedings of the Association of American Geographers, vol. 3, pp. 146-149, 1971.

[10] G. Rushton, "Postulates of central place theory and properties of central place systems," Geographical Analysis, vol. 3, pp. 140-156, 1971.

[11] T. L. Bell, Central Place Theory as a Mixture of the Function Pattern Principles of Christaller and Lösch: Some Empirical Tests and Applications. Unpublished Ph.D. dissertation, Department of Geography, University of Iowa, Iowa, USA, 1973.

[12] T. L. Bell, "Central place theory," in Interpreting the City: An Urban Geography, Truman Hartshorn, Ed. New York: John Wiley and Sons, 1980, Chapter 7.

[13] T. L. Bell, "Central place theory," in Interpreting the City: An Urban Geography, 2nd ed., Truman Hartshorn, Ed. New York: John Wiley and Sons, 1992, Chapter 8.

[14] T. L. Bell, S. R. Lieber and G. Rushton, "Clustering of services in central places," Annals of the Association of American Geographers, vol. 64, pp. 214-225, 1974.

[15] J. Marcus, "Territorial organization of the lowland classic Maya," Science, vol. 180, no. 4089, pp. 911-916, 1973.

[16] T. L. Bell and R. L. Church, "Location-allocation modeling in archaeological settlement pattern research: Some preliminary applications," World Archaeology, vol. 16, no. 3, pp. 353-370, 1985.

[17] R. L. Church and T. L. Bell, "Location-allocation modeling in Archaeology," in Spatial Analysis and Location-Allocation Modeling, G. Rushton and A. Ghosh, Eds. New York: Van Nostrand Reinhold Co., 1987, pp.76-100.

[18] B. E. Kauffman, The Maximal Covering Location Problem as a Simulation of Decision Making in Ramessid Egypt, Unpublished Master's thesis, Department of Anthropology, University of Chicago, 1981.

[19] R. L. Church and T. L. Bell, "An analysis of ancient Egyptian settlement patterns using location-allocation covering models," Annals of the Association of American Geographers, vol. 78, no. 4, pp. 701-714, 1988.

[20] T. L. Bell, M. M. Gripshover and K. T. Rector, "The effects of changing retail patterns on consumer travel behavior," Paper presented at a special session of the 96th Annual Meeting of the Association of American Geographers, Pittsburgh, Pennsylvania, 2000.

[21] E. L. Hillsman and T. L. Bell, "Retailing and public policy: Geographic contributions to the debates," Paper

presented at the 94th Annual Meeting of the Association of American Geographers, Boston, Massachusetts, 1998.

[22] G. P. Stone, "City shoppers and urban identification: Observations on the social psychology of city life," American Journal of Sociology, vol. 60, pp. 36-45, 1954.

[23] J. Baginski and T. L. Bell, "Under-Tapped?: An analysis of craft brewing in the southern United States," Southeastern Geographer, vol. 50, no. 1, pp. 165-185, 2010.

[24] T. L. Bell and L. S. Bell, "Is there a geography of emotion? Lessons learned from the Emo music culture," Paper presented at a special session on music geography at the 99th Annual Meeting of the Association of American Geographers, New Orleans, Louisiana, 2003.

Chapter 4

Studying Human Spatial Decision-making and its Environmental Effects, beginning with an Article by Gerard Rushton

Alan G. Phipps

4.1 Introduction

My research interest in intra-urban residential choice and mobility evolved from Rushton's models of retail consumer spatial behaviors in rural environments. His models theorized residents' choices of dispersed towns for purchases as revealing their preferences for attributes of those places. The theoretical and methodological culmination of his research into consumers' revealed space preferences was, in my opinion, in a relatively early article [1], even though these models have been written about since then [2] [3].

In his article, Rushton [1] begins by proposing a normative decision-rule for residents' choice of the nearest dispersed location for shopping goods and services, and he then deduces the emergent environment in which they would live. He subsequently compares this environment with a more realistic one if residents utilized his computer-simulated decision-rule revealed from observed spatial choices of dispersed locations for goods and services.

His article's four contributions to understanding individuals' and households' spatial decision making are in: (1) Methodology of psychometric methods for decomposing

and interpreting real-world decisions. (2) Theory of human spatial choice, by means of comparison of real-world decision processes with normative and/or experimental ones. (3) Methodology with the use of computer simulation, especially (4) in theory predicting environmental effects on or of human spatial decision-making.

This paper will critically discuss each of these four contributions, and illustrate how my subsequent research has refined them in applications to individuals' and households' residential choice and mobility decisions, as opposed to his retail consumers' spatial behaviors. Regardless of research area, however, Rushton [4, p. 395] was prophetic when he wrote, "...though sufficient has been said to show that the theory of choice as developed in economics and psychology is directly applicable to the problem of spatial choice. This being so, many fruitful lines of inquiry, as well as the methodology for pursuing them, await the geographer interested in individual spatial choice behavior".

4.2 Psychometric Methodology for Decomposing and Interpreting Spatial Decisions

Rushton's primary dataset for his research consisted of up to 603 rural Iowa households' choices of towns for major expenditures on groceries and clothing in spring 1960 or 1961 [5]. His secondary datasets contained comparable earlier choices in 1934 of 5,500 rural Iowa households [6], and later choices in 1966-8 of 287 rural Michigan households [7].

Rushton's [8] major research breakthrough in recovering a space preference function from surveyed households' choices occurred after he discovered a box of computer cards for a non-metric multidimensional scaling program (MDS) in his new university office. This early MDS program required an input matrix of dissimilarities between phenomena of

interest in order to construct a summary interval scale of distances between them [9].

In preparation for calculating what were later called utilities from survey data [10], Rushton firstly conceptualized a consumer's choice of a particular place for major purchase of a good, such as groceries or clothing, as being the result of that consumer's implicit paired comparison with each other potential destination up to a maximum travelled distance. Subsequent researchers have redefined sets of potential destinations to be independent of consumers' observed choices, and have theorized the behavioral consequences of consumers' being spatially indifferent within them [11] [12].

Rushton secondly classified a chosen destination for a purchase and the rejected ones as members of 30-or-more locational types defined in terms of population size groupings and ranges of distances from a household's home. Definition of a dispersed place's attractiveness and accessibility in terms of these two attributes helped to produce an elegant visualizable solution, even if it oversimplified consumer retail choice. Subsequent redefinitions of Rushton's elementary locational types have been with time-distances in a transportation network, number of employees in retailing in shopping centers or zones, and surveyed reasonable travel time for maximum travelled distance [13].

Rushton's MDS calibrated a unidimensional interval scale of utilities for locational types. One output goodness of fit was a consistency index of 0.975 for the transitivity of the original choice probabilities from which were calculated the input dissimilarities [8, p. 216]. Another was a stress index of 0.23 for the calibrated monotonic relationship between those input dissimilarities and the output scaled utilities [14, p. 47].

Both goodness-of-fit indices are more useful for comparisons between different MDS solutions than for absolute determination of goodness of fit [15]. Neither has a

formal statistical distribution and, besides, each has an unintuitive scale. An ideal consistency index above 0.9990 for a transitive matrix will only be decimals-different from a unity upper limit [16]. Correspondingly, an ideal stress#1 value below 0.025 (or double that for stress#2) for a metric preference- or perception-scale's description of ordinal relationships in a proximity matrix will only differ in decimals from a zero lower limit [9] [17]. Moreover, ideal indices do not guarantee interpretable MDS solutions, such as in another study's similarly-positioned shopping centers from consumer ideal points in metric preference space [18].

Rushton confirmed the interpretability of his MDS-calculated interval-scaled utilities for locational types by graphically interpolating isolines of equal overall utility in the form of a three-dimensional 'indifference' surface, with one axis for their population sizes, and another for their distances from households [8, Figure 4.2]. Patronized nearer functionally-complex places were most preferred. Un-patronized farther-away and simpler places were least preferred. And mentally-in-between were places with traded-off combinations of the two attributes.

Each isoline should therefore be monotonically increasing with farther distance to towns and larger town population for residents' deriving constant utility from trading-off farther distances to larger towns. Trade-offs, however, will not be revealed where an isoline of equal overall utility is vertical for a range of town sizes, or horizontal for a range of distances – and definitely not where it has a non-monotonic reversal, such as that of the (-1.5) isoline for towns of approximately 4,000 to 6,000 populations located approximately 3.2 km (two miles) away [8, Figure 4.2].

Graphed isolines between overall utilities without the possibility of statistical errors from MDS thus become a

liability when those isolines are uninterpretable [19, p. 182]. Either the overall utilities are statistically imprecise; or additional information is needed to account for why consumers could have equal utility for a larger town located nearer than a smaller town, or why they could have equal utility for a near or a far same-sized town.

Rushton's [6] further examples of non-monotonic vertical and reversed segments of isolines of equal overall utility on an indifference surface will be discussed below. Additional examples of both vertical and horizontal isolines of equal overall utility are displayed on Lentek, Lieber and Sheskin's indifference surface for food shopping in rural Mexico in 1968 [20, Figure 2]. These authors interpret the vertical segments of utility isolines as representing 637 survey respondents' walking to the nearest center if this was within three kilometers of their homes. Horizontal segments of utility isolines express the spatial indifference of 69 respondents located farther than three kilometers from the nearest food store, who rode the bus to regional centers regardless of distance [20].

On the one hand, these findings for rural Mexicans may confirm that food shoppers do not necessarily trade-off farther distance against larger town population in spatial choices. On the other hand, however, the authors' interpretations are questionable not only as a single indifference surface was calculated for two subsamples with different modes of travel and, thus, dissimilar social and economic costs of travel. They are also questionable if scaled overall utilities were a degenerate MDS solution. The authors' interpolated isolines of equal overall utility only differ in the second decimal, and so, their scaled utilities are quite truncated relative to those in other studies using the same methodology. Neither aforementioned index of MDS goodness of fit is presented by these authors.

Applications of MDS for recovering space preference scales and cognitive distances were popular during the 1970s [14] [21]. I subsequently applied a new individual differences scaling methodology, called the weighted additive model of alternating least squares (WADDALS) for recovering households' utility functions for housing attributes [22] [23].

Just as Rushton had to adapt his MDS program to run on a mainframe computer, I adapted WADDALS to run on a portable personal computer. Mine was also an interactive PC application for graphically displaying WADDALS output in real time, thereby permitting subjects' manual adjustments of computed utilities for levels of attributes [24].

My application of MDS was for measuring individuals' utilities for residential attributes of especially older-urban homes. Another difference was my measurement of stated preferences as opposed to revealed preferences in order not only to circumvent specifying a choice rule [25], but also to have enough data for populating an input data matrix. The data analyzed by WADDALS have a factorial design organization in which hypothetical homes are described with realistic combinations of levels of attributes of the dwelling unit, neighborhood, neighborhood residents, and accessibility.

4.3 Comparison of Real-World Decision Processes with Normative and/or Experimental Ones

Description of behavior in a particular space or during a particular time period was not Rushton's primary theoretical objective. Rather, the theoretical objective was to describe the rules by which alternative locations were evaluated and choices consequently made, and which could produce different observed spatial behaviors in different environments at different times [4].

Independent rules of decision making in diverse spatial systems would thus be theoretical underpinnings for more accurate descriptions of consumer spatial behaviors than those starting with a normative rule of patronizing the nearest place offering a good or service. The evidence for having found these descriptive decision rules would be in consistently-similar indifference surfaces in space and time.

As already mentioned, Rushton analyzed indifference surfaces underlying rural Iowans' shopping choices in the 1930s and 1960s [6] [8], and Michiganders also in the 1960s [7]. As also already mentioned, Lentek, Lieber and Sheskin [20] analyzed food shopping choices of rural Mexicans in 1968. And Timmermans has done likewise for consumer shopping of rural and urban Dutch households during 1977 [3] [13].

For example, Rushton [7, Figure 1] visualized (1) the different spatial behavior patterns of 1960s Iowans and Michiganders in terms of typical distances travelled – but (2) the remarkably similar preference structures for each commodity in two different states – even though (3) small Michigan towns at all distances were more attractive to rural consumers than in Iowa.

He however visualized a significant contrast between 1934 and 1960 Iowans' preference structures. Isolines of equal overall utility on the 1934 indifference surface were almost vertical for choices within eight miles of homes, whereas by 1960 households were substituting a larger town at farther distance for a smaller town at shorter distance [6, Figure 1]. Even so, he did not mention the non-monotonic reversals of the 0 and 0.5 isolines for towns with just-below or just-above 1,000 population located 12 to 14 miles from homes in 1934. He did not mention these even though the revealed utilities were from the choices of 5,500 residents who comprised his largest-ever analyzed sample [6, Figure 1].

Visual comparison was thus the original method for assessing (dis-)similarities between indifference surfaces. Rushton [10] later tested two methods for quantifying the relative importance of the town size and distance attributes in 1960 rural Iowans' scaled utilities for dispersed shopping destinations. One method was statistically fitting a polynomial trend surface to an indifference surface, and another author subsequently applied this to one of his indifference surfaces [13]. A second method was calculating linear and curvilinear coefficients for decomposing attributes' independent and possible joint weights in (non-)additive utility functions [15] [19, p. 187].

Rushton and colleagues, nonetheless, did not rigorously compare their recovered three-dimensional indifference surfaces. They reported seeing both dissimilarities and similarities between those indifference surfaces in space and time. They did this even though dissimilarities might not support Rushton's initial hypothesis about consumers' use of the same independent decision rules for different observed behaviors in space.

Rushton [8, p. 219] from the start acknowledged individuals would be revising their space preferences through time and across space if they were constantly learning about themselves and their environments [26] [27]. In further confirmation of use of different forms of utility functions during a search process [28], I inferred individuals' switching between one form of utility function during an early phase of their search for a new home, and another form in a later phase when making a choice [29]. I also computed similar overall residential stress of their chosen new home at the end of the simulated search process, in comparison with that of their new home in reality – although neither stress was the predicted lowest for them [30].

4.4 Computer Simulation

An aforementioned example of computer simulation by Rushton [1] was in his prediction of the types and spacing of towns if rural residents utilized a decision-rule inferred by him as describing observed choices of dispersed locations for goods and services. He however used a simulated indifference surface for those rural residents' choices, probably owing to his aforementioned inability to statistically summarize the observed one [1, Figure 5]. He subsequently used simulated indifference surfaces to generate consumer choices to test his scaling methodology's ability to calibrate that indifference surface [4] [31].

On the one hand, the axes of his simulated indifference surface have the same scales as those of the observed rural Iowans' 1961 indifference surface [8, Figure 4.2]. On the other hand, however, his simulated surface's utility isolines explicitly converge at zero origin for each axis, whereas those in his observed surface would implicitly converge at zero if respondents could not patronize towns located nearer than 2.5 miles with less than an approximate 400 population. Conspicuously-absent from his simulated indifference surface is a utility isoline resembling the aforementioned non-monotonic (-1.5) isoline on his observed surface.

Computer simulations were not easily executed as batch jobs on mainframe computers, and so, a simulated indifference surface probably simplified a time-consuming procedure, even if the input of a statistical summary of an observed indifference surface was feasible. Interactive CRT computer terminals were available by the time I wrote a computer program in BASIC to computer-simulate an individual's search for a rental apartment [32]. I interestingly remember being challenged with a question that Rushton might have been asked about whether a computer simulation

of human decision-making processes was an unrealistic abstraction of real-world behavior. My most recent computer simulation has consisted of computer-animated online maps and graphs of occurrences of crime and disorder, fires, and house sales in older-urban neighborhoods during periods of time, about which residents answered online survey questions [33].

4.5 Environmental Effects on or of Human Decisions

Finally, Rushton's [1] aforementioned computer-simulation predicted the environmental effects of 1960s rural Iowans' consumer choices as being the growth of larger places at the expense of smaller ones. Rural Iowans' space preferences had reciprocally evolved since 1934 in response to better transportation modes and highway network, and price differentials between small and large stores [5]. Their space preferences were thus the causes and effects of the population dynamics of Iowa villages during the 1960s, which were described in an earlier collaboration [34].

Certainly people need food and clothes to live, and so, they should make voluntary decisions about where to shop for them, even if marketing professionals are always trying to manipulate retail choices. In contrast, some decisions about moving home may be involuntary, or may not have been thought through by individuals or households [35]. Residential choice and mobility decisions may furthermore have serious social, economic and environmental consequences for people and neighborhoods, even though the decision to move into or out of a home is infrequent for most residents. I for example have used utility curves to predict residents' intentions to move out in response to environmental changes in their neighborhoods, such as more distant travel to a school as if resulting from a school closure, and in-

movement of new neighborhood people and housing if different from those already around them [36].

4.6 Conclusion

Even though 1981 is the date of the last publication I have found about his spatial indifference surfaces, Rushton should look back with pride at the continuing relevance of his four research contributions in the study of human spatial decision-making and its environmental effects. The first contribution was his application of psychometric scaling methodology for measuring space preferences, although in reconsidering this I have questioned the undisclosed statistical errors in his unidimensional utility function. I have similarly reconsidered his second contribution of comparing theoretical decision processes with observed or experimental ones. In this, I have questioned whether more rigorous analysis might have contradicted the visualized similarities between indifference surfaces from which were inferred spatially- and temporally-independent rules of decision making. His third contribution was in the use of computer simulation, but I have questioned the particular efficacy of a simulation omitting the contradictory elements of his observed indifference surface. His final contribution was about the environmental effects of or on consumers' spatial decisions, but his research agenda evolved before fully exploring these.

In conclusion, Rushton began his academic career with an innovative theory at the forefront of the quantitative and behavioral revolutions in geography about how individuals made spatial decisions. He wrote clearly and concisely to explain to readers his sophisticated methodology for scaling residents' preferences for consumer shopping locations, and for representing those preferences by means of three-dimensional indifference surfaces of utilities. He anticipated

subsequent criticisms of spatial indifference surfaces in the ways he tested them. His multidimensional scaling methodology attracted the interest of colleagues who applied it for recovering consumers' spatial indifference curves in other countries. My forty-years-late questions in this paper are intended to illustrate at least one former student's continuing interest in the sustainability of his theory of spatial behavior and his methodology for scaling spatial preferences.

References

[1] G. Rushton, "Postulates of central-place theory and the properties of central-place systems," Geographical Analysis, vol. 3 no 2, pp. 140-155, 1971.

[2] J. L. Girt, "Some extensions to Rushton's spatial preference scaling model," Geographical Analysis, vol. 8, no. 2, pp. 137-152, 1976.

[3] H. J. Timmermans, "Spatial choice behaviour in different environmental settings: An application of the revealed preference approach," Geografiska Annaler B, vol. 63,no. 1, pp. 57-67, 1981.

[4] G. Rushton, "Analysis of spatial behavior by revealed space preference," Annals of the Association of American Geographers, vol. 59, no. 2, pp. 391-400, 1969.

[5] G. Rushton, Spatial Patterns of Grocery Purchases by the Iowa Rural Population. Iowa City, IA : University of Iowa, Bureau of Business and Economic Research, Monograph No. 9, 1966.

[6] G. Rushton, "Temporal changes in space preference structures," Proceedings of the Association of American Geographers , vol. 1, pp. 129-132, 1969.

[7] G. Rushton, "Preference and choice in different environments," Proceedings of the Association of American Geographers, vol. 3, pp. 146-150, 1971.

[8] G. Rushton, "The scaling of locational preferences," in Behavioral Problems in Geography: A Symposium, K. R. Cox and R. G. Golledge, Eds. Evanston, Ill: Northwestern University, Department of Geography, Research Paper No. 17, pp. 197-227, 1969.

[9] J. B. Kruskal, "Multi-dimensional scaling by optimizing goodness of fit to a non-metric hypothesis," Psychometrika, vol. 29, no. 1, pp. 1-27, 1964.

[10] G. Rushton, "Decomposition of space preferences and functions," in Spatial Choice and Spatial Behavior: Geographic Essays on the Analysis of Preferences and Perceptions, R. G. Golledge and G. Rushton, Eds. Columbus, OH: Ohio State University Press, pp. 119-133, 1976.

[11] R. Hubbard and A. F. Thompson Jr., "Generalizations on the analysis of spatial indifference behavior," Geographical Analysis, vol. 11, no. 2, pp. 196-201, 1979.

[12] F. Stetzer and A. G. Phipps, "Spatial choice theory and spatial indifference: A comment," Geographical Analysis, vol. 9, no. 4, pp. 400-403, 1977.

[13] H. J. Timmermans, "A spatial preference model of regional shopping behaviour," Tijdschrift voor Economische en Sociale Geografie, vol. 70, no. 1, pp. 45-48, 1979.

[14] R. G. Golledge and G. Rushton, Multidimensional Scaling: Review and Applications. Washington, DC: Association of American Geographers, Commission on College Geography, Technical Paper No. 10, 1972.

[15] F. W. Young, "A model for polynomial conjoint analysis algorithms," in Multidimensional Scaling: Theory and Applications in the Behavioral Sciences, Volume 1 Theory, R. N. Shepard, A. K. Romney and S. B. Nerlove, Eds. New York, NY: Seminal Press pp. 69-104, 1972.

[16] C. H. Coombs, A Theory of Data. New York, NY: Wiley, 1964.

[17] J. B. Kruskal, "Non-metric multi-dimensional scaling: A numerical method," Psychometrika, vol. 29, no. 2, pp. 115-129, 1964.

[18] K. P. Burnett, "The dimensions of alternatives in spatial choice processes," Geographical Analysis, vol. 5, no. 3, pp. 181-204, 1973.

[19] M. F. Goodchild, "Perception, preference and geometry: A commentary," Spatial Choice and Spatial Behavior: Geographic Essays on the Analysis of Preferences and Perceptions, R. G. Golledge and G. Rushton, Eds. Columbus, OH: Ohio State University Press, pp. 179-188, 1976.

[20] B. Lentek, S. R. Lieber, I. Sheskin, "Consumer behavior in different areas," Annals of the Association of American Geographers, vol. 65, no. 4, pp. 538–545, 1975.

[21] J. B. Kruskal and M. Wish, Multidimensional Scaling, Sage University Paper Series on Quantitative Application in the Social Sciences, 07-011. Beverly Hills, CA and London, UK: Sage Publications, 1978.

[22] A. G. Phipps and J. E. Carter, "Individual differences in the residential preferences of inner-city homeowners," Tijdschrift Voor Economishe en Sociale Geografie, vol. 76, no. 1, pp. 32-42, 1985.

[23] Y. Takane, F. W. Young, and J. de Leeuw, "An individual differences additive model: An alternating least squares method with optimal scaling features," Psychometrika, vol. 45, no. 2, pp. 183-209, 1980.

[24] A. G. Phipps and W. A. V. Clark, "Interactive recovery and validation of households' residential utilities," in Behavioral Modelling in Geography and Planning, R. G.

Golledge and H. J. Timmermans, Eds. London, UK: Croom-Helm, pp. 245-271, 1988.

[25] G. H. Pirie, "Thoughts on revealed preference and spatial behaviour," Environment and Planning A, vol. 8, no. 8, pp. 947-955, 1976.

[26] D. Maclennan, N. J. Williams, "Revealed space preference theory – A cautionary note," Tijdschrift voor Economische en Sociale Geografie, vol. 70, no. 5, pp. 307-309, 1979.

[27] H. J. Timmermans and G. Rushton, "Revealed space preference theory – A rejoinder," Tijdschrift voor Economische en Sociale Geografie, vol. 70, no. 5, pp. 309-312, 1979.

[28] H. J. Timmermans, "Consumer spatial choice strategies: A comparative study of some alternative behavioural spatial shopping models," Geoforum, vol. 11, pp. 123-131, 1980.

[29] A. G. Phipps, "Utility function switching during residential search," Geografiska Annaler, vol. 65B, pp. 23-38, 1983.

[30] A. G. Phipps, "Rational versus heuristic decision making during residential search," Geographical Analysis, vol. 20, pp. 231-248, 1988.

[31] G. Rushton, "Behavioral correlates of urban spatial structure," Economic Geography, vol. 47, no. 1, pp. 49-58, 1971.

[32] A. G. Phipps and P. Frankland, "The geographic application and validity of two human-computer simulation games," The Canadian Journal of Simulation and Gaming, vol. 19, pp. 69-87, 1983.

[33] A. G. Phipps, "Comparisons of residents' perceptions of patterns and trends on computer-animated maps and graphs and on Google maps of events in their

neighbourhoods," Cartographica, vol. 46, no. 3, pp. 185-199, 2011.

[34] N. E. Salisbury and G. Rushton, Growth and Decline of Iowa Villages: A Pilot Survey. Iowa City, IA: State University of Iowa, 1963.

[35] A. G. Phipps, "Unexpected life events as improbable reasons for moving house: A review of two studies' findings," International Journal of Migration and Residential Mobility, vol. 1, no. 2, pp. 163-175, 2015.

[36] A. G. Phipps, "Intended-mobility responses to possible neighbourhood change in an American, a British, and a Canadian inner-urban area," Tijdschrift voor Economische en Sociale Geografie, vol. 80, no. 1, pp. 43-57, 1989.

III. Economic Geography

In the first of two chapters on research in Economic Geography, Mike Goodchild compliments Rushton for contributing to his evolution from a graduate student studying karst geomorphology to a protagonist of geographic information science in the face of humanist critiques. Tom Eagle then demonstrates the application of Rushton's decision support system with spatial statistical analysis and GIS for predicting retail sales at existing and new stores of a client in the private sector.

Chapter 5

Gerard Rushton and Quantitative Human Geography

Michael F. Goodchild

5.1 Introduction

In this paper I would like to trace the intellectual connections between Dr. Gerard Rushton and me, and the convergences and divergences in our research over the past 50 years. In doing so I hope both to pay tribute to him, and to provide a model of the development of human geography and geographic information science (GIScience) over that period, including debates that have swirled around these fields. My model is of course a personal assessment, and I would not expect every human geographer or GIScientist to agree with me, especially regarding what I present as a recent rapprochement between positions that at one time were diametrically opposed.

5.2 Early Encounters

I arrived at McMaster University in September of 1965 to enroll in the graduate program in geography. I had received a BA in physics from Cambridge University that June, and had immediately left for what turned out to be a very exciting summer exploring caves in the Canadian Rockies, and the first field season of what I had planned to be a Ph.D. in cavern genesis under Dr. Derek Ford. My enthusiasm had waned considerably by September, however: The Province of

Ontario is located a long way from challenging caves, and since I had never studied geography in any depth the department was insisting that I take a qualifying year of undergraduate courses. Derek's Geomorphology was central to my interests of course; Microclimatology was marginally relevant to cavern genesis; and Andy Burghardt's Regional Geography of the US was fascinating; but what was the point of requiring me to take Urban Geography, taught by a very young assistant professor, named Gerard Rushton?

By the end of that year Gerry's course had given me an appreciation of human geography that has lasted all my life. He began by insisting that students learned to program in FORTRAN, a daunting challenge for most of the class. At the time the department had an outstanding group of graduate students, many of whom were eager to collaborate with someone who could program, and to bring the new tools of the quantitative revolution to their own research.

I was puzzled, though, by this concept of quantitative human geography, and the theory of central places (CPT) that occupied much of Gerry's course. Geographers had been ransacking reality looking for settlement patterns that formed hexagons but found none, even in the flat, uniform, and seemingly boundless plains of the US Midwest, let alone Denmark, Southern Germany, Brazil, or Snohomish County, Washington. To a physicist fresh from the Cavendish Laboratory of Ernest Rutherford, a theory that was not empirically verifiable was no theory at all. Patterns of human settlement were clearly not random, and the populations of adjacent settlements were somewhat related; but I was able to show in an early paper that if the assumptions of the theory were even minimally untrue, the entire edifice of nested hexagons collapsed [1].

The philosopher Bertrand Russell was fond of an anecdote about Euclid's axioms. On first encountering them he was puzzled by their lack of logical or empirical foundation – why should he accept them? His mentor pointed out that unless he did, it would be impossible to go further, since discussion would be bogged down in an argument that could have no ending. This issue of the empirical foundations of CPT struck me as similar: If we accepted the assumptions, then the logical consequence was a pattern of great symmetry and beauty, an intellectual sandbox in which we could play endlessly. Moreover, CPT would always provide an abstract norm against which the real world could be compared. Better surely to compare reality to CPT than to a null hypothesis of randomness.

Rushton was clearly concerned about the same issue, as his intellectual migration into behavioral geography occurred at about this time [2]. If the simple assumptions of Christaller [3] and Lösch [4] about human behavior were not accurate, then perhaps the techniques of revealed space preference could provide better alternatives. With colleagues, he began assembling the techniques needed to develop better models of behavior (e.g., [5]), and ultimately a better understanding of how humans learn and make choices within complex environments.

My own thinking took a slightly different track that was more concerned with reconciling my background in physics with the realities of geography. Both physical and human geography must deal with a world that is essentially messy, in which perfect explanation or prediction is never achievable—in which the R-squared of a model can never be unity, and residuals will always be non-zero. There is no doubt, however, that models in the social and environmental sciences will always be underspecified, because there will always be variables that are overlooked. Moreover, Tobler's First Law

[6] ensures that variables will always exhibit positive spatial dependence, including residuals, making any process of estimation problematic. Under such circumstances we should strive not to achieve perfect prediction, but to reduce uncertainty as much as possible.

5.3 Normative Thinking and Applied Geography

Even so, another line of thinking turned out to be equally or even more productive: Rather than try to explain the complexity of human behavior and settlement patterns, why not develop techniques for *designing* patterns to achieve desirable objectives? Geography as a discipline might therefore be usefully engaged in improving the world in addition to understanding and explaining it. In the public sector it is often possible to allocate people to central facilities, such as schools, without being concerned with modeling the somewhat chaotic behavior of people who have choices. In the private sector, modeling of consumer spatial behavior, while not perfect in its predictions, might at least reduce uncertainty sufficiently to be useful. In the words of George Box [7, p. 424], "all models are wrong but some are useful."

By the time Rushton left McMaster University for Michigan State University, Bryan Massam and I were busily programming the university's IBM 7040 to design optimal arrangements of central facilities, following this essentially normative approach and with Gerry's guidance and encouragement. Our first paper compared Ontario's actual system of regional centers to systems designed to achieve specified objectives, such as minimizing the average separation of centers and the public [8]. The term *location-allocation* became current at about this time, with a seemingly infinite range of assumptions, objectives, and applications

about how to locate central facilities to serve a dispersed population. The field of applied geography eventually focused much of this activity.

When Rushton returned to the University of Iowa in the late 1960s he began supervising a group of graduate students focused on this combination of behavioral and normative geography. In 1973 he organized an event that turned out to be career-defining for many young geographers. This was an extended two-week institute on the instructional use of computerized algorithms for solving location problems, funded by the National Science Foundation (NSF). He invited me to participate as an instructor.

In 1977 Jonathan Halpern and I organized an international symposium on locational decisions in Banff, Alberta, the first of the triennial ISOLDE conferences. This helped to broaden the disciplinary base of location-allocation, by including management scientists, civil and industrial engineers, and economists, alongside geographers. Another thread emerged around this time when Rushton obtained funding, initially from the Ford Foundation, to apply some of these methods to design networks for the provision of public services in rural India. He invited me on many of these trips, which involved adapting our code to run on the very simple minicomputers and microcomputers that became available in India during a period of embargo on foreign-sourced hardware.

This idea of using geographic techniques for normative ends proved to be a very useful product of the quantitative revolution. However, the tide turned in the 1970s and an extensive critique of scientific or 'positivist' geography emerged. Even so, some of us were able to maintain successful careers around location-allocation, geographic information systems (GIS), and other approaches that were more oriented to practical usefulness. These approaches were

ultimately more successful than previous work in demonstrating the importance of geography and geography's perspective on problem-solving.

Coincidentally, one of the persistent themes explored by Rushton in his urban geography course at McMaster was the Hartshorne/Schaefer debate (e.g., [9], [10]). This was at the time and still is today a key element in discussions over the philosophy of geography. Should geography be devoted to the search for universal truths, in the style of physics, or to the detailed description of the unique properties of places?

From a normative perspective, one might respond that geography should be concerned both with finding universal truths that support a useful level of prediction, and with documenting the properties of places to serve as initial or boundary conditions for those predictions. For example, to design a new shopping center one needs to be able to predict spatial behavior with respect to proposed locations at an adequate level of accuracy, and also to have detailed demographic information about the surrounding population. To this new generation of normative geographers, therefore, the Hartshorne/Schaefer debate was largely resolved: Clearly one needs both if one is to use geographic principles to intervene in the real world by devising improved designs. In GIS, one would identify the software as representing general truths, and the database as descriptive of local conditions.

5.4 The Fork in the Road

By the late 1970s it was clear that another theme had emerged to divide the discipline. This was between the remnant quantifiers, now pursuing both normative and scientific paradigms, and the critical social theorists and their allies, who rejected quantification and sought humanist alternatives to the scientific geography of Bunge [10] and

others. Initially trained in geography, these latter critics had by the late 1980s begun to be trained in cartography [11] and later GIS [12].

There were many dimensions to the critique. Smith [13] argued that much of the funding and innovation that led to GIS originated with the military, and yet the literature of GIS and especially its textbooks were apparently reluctant to acknowledge the fact. Jordan [14] called GIS "non-intellectual expertise," arguing that it had no place in the academy. Departments resented the investments they were being asked to make in support of courses in GIS. Curry [15] saw GIS as a central element of the "surveillant society." Others criticized GIS as a tool of power, leading to further marginalization of the less advantaged sectors of society. GIS was naïve and simplistic in its representation of the world, replacing subtle gradations with sharp boundaries and Boolean logic. And in the words of Peter Taylor, GIS was the "quantifier's revenge" [16]. Much of this was coincident with the establishment in 1988 of the National Center for Geographic Information and Analysis (NCGIA), a major investment by NSF dedicated to advancement of GIS and its promotion throughout the social and environmental sciences.

There was clearly a need for rapprochement, and the two sides were brought together at important meetings in 1993 and 1995. GIS was evolving rapidly, and many of its developments could be seen as addressing elements of the critique. Initiatives such as public-participation GIS aimed to bring the technology to the community, while the entry cost of GIS continued to plummet, so that today it is available in limited form to anyone equipped with a smart phone. Community-based GIS is widely available in the form of OpenStreetMap, Ushahidi, and other tools that have proven remarkably influential in dealing with crises and promoting change. Today the GIS services that are delivered to the

public through smart phones are no longer limited to the "god's-eye view" of the empowered. These GIS service are also much more centered on the specific needs of the consumer for current, relevant, and helpful information services.

Nevertheless, critique is perhaps more important now than it ever was. Surveillance is pervasive, whether from street cameras or drones, aided by dramatic advances in face-recognition technology. GIS is widely available, and widely abused. The tools being produced by the private sector and the open-source community are seldom if ever subjected to peer review. While the development of GIS and other geographic technologies are the responsibility of academics, the private sector, and increasingly the general community, only the academic community has the recognized responsibility to reflect on the technology and its uses and societal impacts.

If GIS might be labeled as non-intellectual button-pushing and as having no more fundamental academic value than a word processor, then the other side could clearly claim the academic high ground. In the early years of NCGIA we were much exercised to make the intellectual case for GIS, and more broadly for scientific geography. David Simonett, the founding Director of NCGIA, was adamant that GIS should develop theory and principles, a theme that I explored [17]. These principles I anticipated could come from research in geography – what empirical principles structure the geographic world, and enable the development of effective representations in GIS?; cognitive science – how do people reason and learn about geography, and how can that knowledge improve the GIS user's experience?; spatial statistics – how can we model the uncertainty that is present in all geographic information, and present knowledge of uncertainty to the GIS user?; and of course computer science

– spatial databases, computational geometry, etc. Since then GIScience has been widely recognized as a useful term, and much progress has been made in identifying both its empirical and its theoretical principles (e.g., [18]).

5.5 Assessment

So what can we learn from all this? First, I was extremely lucky to find a young, stimulating assistant professor in quantitative human geography at a department that I selected for entirely different reasons. I cannot imagine how my career would have turned out if I had not been required to take Rushton's undergraduate course at McMaster University in 1965. Although cavern genesis is interesting and gave me a very satisfying topic for my doctoral dissertation, I would certainly not have found the fertile and ever-expanding ground in karst geomorphology that I found in human geography and the GIScience to which it led.

Second, I was fascinated by Rushton's ways of thinking and argument, which differed so strongly from the modes I had experienced in physics, and were constantly evident in his class and in conversation. His reasoning is intuitive, rather than grounded in mathematics, and he is strikingly persistent in how he worries a problem to a solution. He is renowned for his critical faculties, and for the outstanding series of graduate students who have emerged from his supervision and gone on to careers in many disciplines and fields.

Third, he has been a pillar of the school that emerged during the quantitative revolution of the 1960s, migrated to behavioral geography, and then adopted the principles of GIScience in the 1990s. Without him and others who followed similar paths, it is doubtful that quantitative human geography could have survived, or achieved the rapprochement that occurred at the end of the century.

Looking around the world, it is evident that quantitative human geography is alive and well in the US, but it would be hard to say the same about many other developed countries that have equally long or longer traditions of geography.

Looking back, it is clear to me that all of my encounters with career-defining mentors have had an element of happenstance rather than design. At McMaster both Rushton and Dr. Derek Ford were strong mentors, and champions when I ran afoul of some of the senior and more traditional faculty. I hope I have been able to deliver adequately on the promise both saw in me.

References

[1] M. F. Goodchild, "The trade area of a displaced hexagonal lattice point," Geographical Analysis, vol. 4, pp. 105-107, 1972.

[2] G. Rushton, "Analysis of spatial behavior by revealed space preference," Annals of the Association of American Geographers, vol. 59, no. 2, pp. 391-400, 1969.

[3] W. Christaller, Central Places in Southern Germany, C.W. Baskin, translator. Englewood Cliffs, NJ: Prentice-Hall, 1966.

[4] A. Lösch, The Economics of Location, W. H. Woglom and W. F. Stolper, translators. New Haven, CT: Yale University Press, 1954.

[5] R. G. Golledge and G. Rushton, Multidimensional Scaling: Review and Geographical Applications. Washington, DC: Association of American Geographers, 1972.

[6] D. Z. Sui, "Tobler's first law of geography: A big idea for a small world," Annals of the Association of American Geographers, vol. 94, no. 2, pp. 269-277, 2004.

[7] G. E. P. Box and N. R. Draper, Empirical Model-Building and Response Surfaces. New York: Wiley, 1987.

[8] M. F. Goodchild and B. H. Massam, "Some least-cost models of spatial administrative systems in Southern Ontario," Geografiska Annaler, vol. 52B, pp. 86-94, 1969.

[9] F. K. Schaefer, "Exceptionalism in geography: A methodological examination," Annals of the Association of American Geographers, vol. 43, pp. 226-245, 1953.

[10] W. Bunge, Theoretical Geography. Lund: Gleerup, 1966.

[11] J. B. Harley, The New Nature of Maps: Essays in the History of Cartography. Baltimore: Johns Hopkins University Press, 2001.

[12] J. Pickles, Ground Truth: The Social Implications of Geographic Information Systems. New York: Guilford, 1995.

[13] N. Smith, "History and philosophy of geography: real wars, theory wars," Progress in Human Geography, vol. 16, no. 2, pp. 257-271, 1992

[14] T. Jordan, "The intellectual core: President's Column," Newsletter of the Association of American Geographers, vol. 23, p. 1, 1988.

[15] M. Curry, Digital Places: Living with Geographic Information Technologies. New York: Routledge, 1998.

[16] P. J. Taylor, "GKS", Political Geography Quarterly, vol. 9, no. 3, pp. 211-212, 1990.

[17] M. F. Goodchild, "Geographical information science," International Journal of Geographical Information Systems, vol. 6, no. 1, pp. 31-45, 1992.

[18] P. F. Fisher, Classics from IJGIS: Twenty years of the International Journal of Geographical Information Science and Systems. Boca Raton: CRC Press, 2007.

Chapter 6

Integrating a Hierarchical Bayes Gravity-like Model into a Retail Chain's IT System

Thomas C. Eagle

6.1 Introduction

My professional career after graduating as one of Dr. Gerard Rushton's doctoral students in Geography took a path into marketing research and consulting where I became an 'engineer' instead of an academic. My key job was and has been to find solutions to complex marketing questions that almost always involve the modeling of consumer behavior. This over time has demanded the solution of more and more complex problems with large data sets and systems of models in order to capture the nuances of behaviors that clients wish to predict.

Also as time has gone by, more clients have needed a Decision Support System (DSS) in order to understand the predictions of our analyses. These systems were and still are theoretically inelegant or imperfect. Engineers in the business world tend to solve extremely complex problems in a short time frame, frequently with poor data, and in the face of client constraints. Prediction often outweighs explanation. From my perspective, one of Rushton's greatest influences was to shape the way I could tackle and develop systems of models that described or predicted these data [1].

These subsequently for me have included systems for modelling the impacts on company profits of pricing and

availability of menu items in fast food restaurants, sandwich chains, and full service restaurants; for developing optimization systems to maximize profits for major airlines; for customizing the market segmentation of the research division of a major energy provider in terms of specific strategic and tactical requirements; and for integrating a hierarchical Bayes gravity-like model into the IT system of a major national retail chain.

We do not explain the theory and procedure of hierarchical Bayes modeling used in this representative DSS for integrating a hierarchical Bayes gravity-like model into the IT system of a major national retail chain. Nor can we show the details of the final system of models as this is proprietary to the client. We therefore discuss the general details of the modeling framework and the data included in, and excluded from, the calibrated model; how it was integrated into the client's IT system; and how it is now being used firm-wide.

6.2 Introduction to one of my Company's DSS

This client's posed problem is indeed representative for me: A major national retail sales chain required a better process and statistical model to predict the viability of potential new store locations. Members of the chain's site evaluation team previously examined sites by hand. They had access to an aggregate distance decay model for predicting shares of sales in block groups around new sites. Their model however did not incorporate sales potential, the impact of competition, the impact of sister stores in the same spatial area, or the characteristics of the new market area itself on the predictions. No updating of the model or its predictions was available. The aggregate distance decay model was

incorporated into a GIS, but it was a standalone model used only by the site evaluation team.

We proposed to improve this system in at least three ways by: (1) Improving the predictions of the model at the block group level for aggregate average weekly sales in stores, while incorporating competitive and existing sister store impacts. (2) Integrating the modeling system into the chain's IT system to enable both seamless use of GIS and storage of data internally in the chain's IT system, together with updates under their control. (3) Developing a system that would allow the site evaluation team to calculate new predictions for others to use in a controlled way if they inserted new stores, competition, and altered parameters.

6.3 The Modeling System

Hierarchical Bayes (HB) models were used to comprise a store site sales evaluation system. Hierarchical Bayes models are a form of multi-level random effects models, and their conceptual structure is illustrated in Figure 6.1 (e.g., [2, 3]). There is an upper-level model governing the heterogeneity across the lower-level model. The lower-level model is a gravity-like model predicting share of sales from each block group comprising the market area. One result of using the hierarchical Bayes model is that each existing store has its own set of estimated gravity-like model parameters across the posterior draws of the Monte Carlo Markov Chain simulations.

The upper-level model therefore governs and predicts the lower-level model parameters. This upper-level model was a multivariate regression of the lower-level gravity-like model parameters on the set of store and market area specific characteristics. This upper-level multivariate regression model may consequently produce predictions of lower-level

model store parameters for a new site with assumed store and market area characteristics. The first statistical objective is therefore to produce a reasonable upper-level model to predict a store's lower-level gravity-like model parameters. Then, the second statistical objective is to predict a set of new site-specific gravity-like model parameters that would improve upon those of the original aggregate gravity-like model used by the chain.

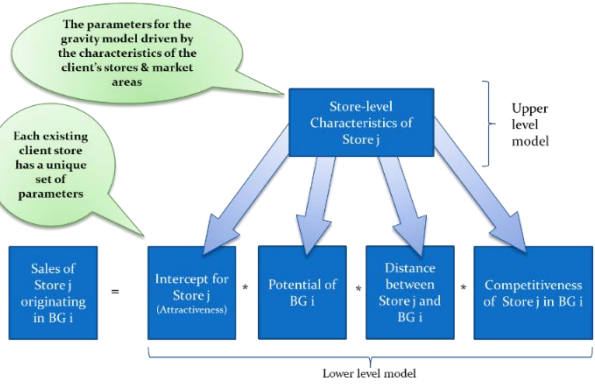

Figure 6.1 The basic Hierarchical Bayes model. (Color copy online.)

Existing store sales and market area data were used as data for calibrating the model. In the HB framework, each store has parameters estimated for the variables used to represent the lower-level model components. This model predicts the sales originating from each block group. Each store's market area and store-level characteristics are used in the upper-level of the HB modeling to predict the values of its lower-level gravity-like parameters. The final estimated model is essentially a zero-inflated binomial model of the proportion of block group sales captured by the chain's stores.

There however were particular data constraints for this modeling. For example, the sales data originating from each

block group was incomplete, so that there was an unknown amount of spatially-incomplete information in the dependent variable of our model. A system of hierarchical Bayes models was constructed to account for this uncertainty in the dependent variable. The system ultimately consisted of a model to predict the likelihood of sales originating for each block group, followed by a model predicting the share of sales from each block group inferred from the likelihood of sales originating there. The same set of upper- and lower-level model predictors were used in both models.

6.4 Data

The market area for each store was designated as the 10-mile radius around each one. Within that 10-mile radius we had 1-mile, 3-mile, 5-mile, and 5 to 10-mile aggregated zonal census and food sales data (other zonal boundaries were examined as well). These data were subjected to a principal components analysis to reduce the number of variables and thus remove their multicollinearity. Multivariate regressions in the upper level model also included independent variables for each store's unique characteristics, including gross square footage, retail sales footage, and store experts' qualitative and quantitative measures of the site's characteristics. These latter measures included ease of access to the store and parking; location relative to major thoroughfares, the CBD, trains and subways; and information about the locations and strengths, or potentials of sister stores and the store's competition.

Last, data for the surrogate of the weekly sales data originating from each block group were incomplete and did not aggregate up to the average weekly total sales in stores. We had many block groups with zero sales when, in fact, sales likely did originate from those block groups. As a result, a zero-inflated hierarchical Bayes model system was

developed. One model component predicts the likelihood of any sales originating from a block group; and then a second component predicts the share of sales from the block group based upon the likelihood of any sales from the block group.

Otherwise, block group potential data included all the available census information, sales data for various categories of food purchases, total sales potential (total dollars spent on food items in the block group), and its location. A principal components analysis was conducted similarly to the upper-level model using these data across all block groups in the US. The resulting factor scores were measures of block group potential.

Straight-line distance measured in miles from each block group to each store was used in the models. Road distances and travel times that were either directly measured or computed from GIS system capabilities were not used at the direct request of the client. Our model as a result does not capture the direct impact of any spatial barriers that may influence the shoppers' behaviors.

One of four indices of the impact of competition on the sales originating from each block group was a distance-weighted index for the strength of each competitive store within a 10-mile radius of each block group. In addition, a distance-weighted intervening opportunity index was calculated in an analogous manner. These two indices were also computed for the client's sister stores within the 10-mile radius of each block group. These were adapted from the original ones of another author for measuring patient flows using Bayesian methods [4]. Zonal summary measures of these competitive indices were used in the upper-level model.

6.5 Estimation and Final System of Models

The models were calibrated with available Markov Chain Monte Carlo (MCMC) routines that utilized a Gibbs Sampler to predict the binomial likelihood of (1) sales originating from each block group; and (2) the proportion of a block group's total sales potential going to the client's store based upon the likelihood of sales originating from that block group. These models were validated using a hold-out sample of existing stores.

This series of calibrated models were further refined for sales' predictions in stores under competition from nearby sister stores and competitive stores. The final system of models predicted average weekly stores sales both with good statistical explanation (R-squared of 65%), and in comparison with actual average weekly sales (Figure 6.2). Note that the aggregate analogous gravity-like model had a much lower R-squared of 26% explained variation.

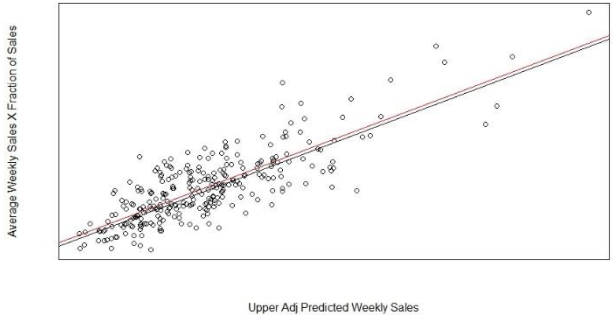

Figure 6.2 Predicted versus actual average weekly store sales from the modeling system. Note the upper (red) solid line is the simple regression of predicted sales on actual sales, and the lower solid line is the diagonal. (Color copy online.)

6.6 Integration of the Modeling System into Retail Chain's IT system

In the end, the lack of a centralized IT system across the units of the client's organization presented a unique system's development issue. These units included marketing, site planning, advertising, and sales – and the modeling system obtained data from some of these units and IT. Channels allowing access to these data were required. An integrated data access system was constructed for the modeling system's acquisition of required data with minimal user input. This unified the different data contained across these systems, the coordination with the client's IT group, and the knowledge of required inputs for the modeling system. Data were in some cases transferred to a centralized system; while in other cases direct access channels were developed.

Model results were also networked within the chain's IT system. The modeling system was designed for a user to simulate new and existing store sites and to view results. The user has the option of saving the results locally. Simulations thought to be useful for storing in the chain-wide data base are submitted to a modeling system administrator for him or her to evaluate and to approve a request for storage of results in the chain-wide IT system. Saved results and inputs may be called from the IT system, but not modified without an administrator's approval. Of course, the chain's IT system administrators were heavily involved in the design and implementation of the data access and storage system (Figure 6.3).

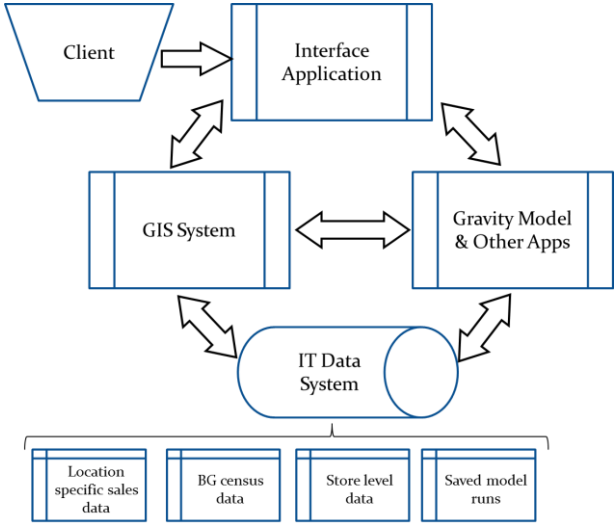

Figure 6.3 Representation of the implemented IT system. (Color copy online.)

The user interface was implemented within the GIS system using the GIS system's programming language. Some modules were written for executing routines outside of the GIS system. These modules ran the modeling system and saved results appropriately. The basic modeling system is run from a designed user interface that permits a user without GIS-knowledge to evaluate a site. Evaluation of a new site requires additional inputs including the longitude and latitude of the new site; the site's required physical and evaluative characteristics; and the type of tabular and/or mapping reporting desired by the user.

The user interface when reloading an existing store's site and model results, promotes 'what-if' scenarios from changing the existing store's characteristics; changing existing sister and competitive store characteristic; and inserting new competitive and sister stores into the market area and evaluating the impact of these new stores on existing

stores. Furthermore, an expert user with knowledge of GIS may adjust predictions down to the block group level, modify the aggregate store predictions, and alter model system inputs to refine the modeling system's results. An expert can thus refine the new or existing store's results using first-hand knowledge not included in the modeling system.

6.7 Conclusion

The modeling system has now been fully integrated into the firm-wide IT system, for example, with the results that: (1) The process of evaluating new sites has been streamlined. (2) There have been more accurate predictions of store sales at new sites opened since the modeling system was implemented. (3) Various units across the retail chain not directly linked to site evaluation are using the system to improve marketing strategy, customize store inventory, and evaluate new store concepts.

Finally, the modelling system is re-estimated and refined on an annual basis. Furthermore, the retail chain continues to request model refinements for the improvement of outlier predictions, and new applications beyond its original scope. Such requests are a clear sign of the integration of a complex modeling system into a company-wide environment. The modeling system's developers are always striving to improve its predictions as well as expanding its capabilities to address more specific and refined requests.

References

[1] G. Rushton, "The Roepke Lecture in Economic Geography: Location theory, location-allocation models, and service development planning in the Third World," Economic Geography, vol. 54, no. 2, pp. 97-120, 1988.

[2] P. D. Congdon, Applied Bayesian Hierarchical Methods. London, UK: CRC Press, 2010.

[3] J. LeSage and R. K. Pace, Introduction to Spatial Econometrics. London, UK: CRC Press, 2009.

[4] P. D. Congdon, "A Bayesian approach to prediction using the gravity model, with an application to patient flow modelling," Geographical Analysis, vol. 32, no. 3, pp. 183-197, 2000.

IV. Health Geography

In the first of three chapters on research in Health Geography, Kirsten Beyer critically analyzes Rushton's pioneering work in disease mapping for realizing positive impacts of lessons from Dr. John Snow, such as, about geographic scale in spatial patterns of disease, and translation of research findings into interventions to improve health. Ellen Cromley in the next chapter refines Rushton's analysis of individual-level geocoded health data for demonstrating the colocation quotient as a measure of spatial association among categories in a population who have global and local patterns of successful and unsuccessful aging. Sara McLafferty, Avijit Ghosh and Jamie Fishman in the final paper also apply Rushton's locational analysis research as a framework for an empirical analysis of inequalities in spatial accessibility to primary care physicians in the Chicago region, including those who are international medical graduates.

Chapter 7

The Lessons of Dr. John Snow: A Call for Translational Health Geography

Kirsten M. M. Beyer

7.1 The Lessons of Dr. John Snow about Geographic Scale and Translation of Findings

Dr. John Snow hypothesized that cholera was a water-borne disease, and so, he plotted deaths from cholera in Soho district of London, UK, on a dot map, and identified the Broad Street pump as the likely source of the epidemic. In a triumphant action that makes him a central figure in the fields of epidemiology, geography and others, he persuaded authorities to remove the pump handle, and the epidemic was put to an end [1] [2]. Regardless of whether this story is legend and independent of the chronology of events [1], Snow's investigation reminds us about the salience of (1) geographic scale in examining spatial patterns of disease and relationships between health and the environment; and (2) the translation of research findings about these patterns and relationships into interventions to improve health.

Each and every disease or health outcome creates a spatial pattern [3], and so, questions of scale are paramount if the investigation of a phenomenon at a particular geographic scale can distort statistical results and alter observed patterns [4]. In reality, the detection of a spatial pattern requires the alignment of the scale imposed by the analyst with the scale at which the phenomenon varies spatially [5]. If Snow had examined the outbreak at a different geographical scale, he

may not have identified the observable spatial distribution of cholera cases [6].

Health researchers' focus on the local scale has caused an increase in research into community, neighborhood, and built environment factors influencing health, and the mechanisms for these influences [7]-[11]. A sole focus on individual-level risk factors may exclude community and other socio-structural conditions that also affect risk [12].

Furthermore, interventions for structural changes can have a larger impact on population health than those just for individual-level changes [13]. For example, neighborhoods are shaped by social and economic processes, and are thus amenable to modification, presenting a promising avenue for effective public health intervention [9] [14] [15]. At the same time as the focus has turned to the local scale rather than just the individual level, there has been a growing realization about the roles of global processes and factors. These include global climate change in altering spatial distributions of environmental hazards and disease burdens, as well as having implications for social justice and health disparities [16] [17].

Perhaps as important as Snow's focus on local geographic scale was his action after the discovery of the contamination caused by the Broad Street water pump. The growing urgency for this type of reaction of 'removing the pump handle' is revealed by the growing popularity of what is termed translational research. Translational research "transforms scientific discoveries arising from laboratory, clinical, or population studies into clinical applications to reduce [disease] incidence, morbidity, and mortality" [18]-[20].

In particular, evidence of the existence of health disparities among different population groups has mounted [21]-[23]. Action to mitigate disparities has been suggested repeatedly in the literature, often in conjunction with a

suggestion of partnerships with affected communities [12] [24] [25]. These community-engaged research approaches seek to re-center power in research by involving subjects of research in all phases of the research process, such as, from formulation of questions to dissemination and use of results. Empowerment of communities for their own destinies is therefore a driving force necessary for mobilizing action [12] [25].

7.2 Challenges to Translational Health Geography

Nevertheless, community-engaged health research approaches may have special challenges for geographers if geographic information system (GIS) technology is utilized. A primary challenge is the tension between geographical scale and data confidentiality. Access to relevant spatial data has been described as "the single hardest part of the GIS adoption equation" [26].

The release of health data for research purposes is subject to regulations for protecting privacy and confidentiality, and these may limit both the geographic scale of available data and authorized users. The Privacy rule issued pursuant to the Health Insurance Portability and Accountability Act (HIPAA) of 1996, sets forth certain requirements for de-identification of protected health information in the United States, including the removal of detailed geography. Researchers can obtain data through data sharing agreements with data holding agencies, but the latter may stipulate data handling, data release, presentation, and storage practices.

Moreover, while agreements can be written to allow analyses of detailed geographic data, they often limit the depth of those analyses [10]. Some researchers have reported difficulties in achieving Institutional Review Board (IRB) approval for research projects incorporating community

participation, as the status of community members confuses the definition of research subjects [27]. As Malone et al. [27] note, "we may need to consider how the current ethics culture of academia may have the effect of protecting institutional power at the expense of community empowerment". GIS functionality may thus be limited to basic choropleth maps of administrative units in public participation geographic information systems (PPGIS) projects where community members are incorporated as hands-on GIS users.

Even so, basic mapping with bounded units may produce spurious statistics, confused relationships, and mis-interpretation, due to the so-called small numbers problem and the aforementioned modifiable areal unit problem [28]-[31]. Merrick [32] has especially argued for participants' having a basic understanding of spatial concepts (distance, proximity, scale), cartographic principles (projection, symbolization, classification, hierarchy, color), and the GIS requirements for different types of analyses as well as an ability to operate the computer software. An expectation for community members' achieving these levels of expertise and understanding, often within a brief period, may be unrealistic.

7.3 Gerard Rushton's Contributions

Notwithstanding the foregoing, spatially filtered maps may contribute to overcoming technical and social challenges to a translational health geography, and Rushton and colleagues have now published extensively about spatial filtering methods [33]-[39]. Adaptive spatial filtering uses a pre-specified grid of estimation points and overlapping spatial filters that iteratively aggregate data from nearby areas, expanding variably across the study area to stabilize the population included in rates' calculations. The result is a map that displays disease rates as a continuous surface. This spatial

filtering approach using adaptive bandwidth filters achieves at least three essential properties for disease maps: (1) Controlling the population basis of support used to calculate a rate; (2) displaying rates continuously over space; and (3) providing maximum geographic detail across the map [34].

Spatially-filtered maps may therefore enhance public access to spatially-detailed information on disease risk, thereby including community partners and public audiences who may not be sanctioned analysts of confidential disaggregate health data. But what must be done to leverage these maps as agents of information and change to improve population health? Four community-engaged research projects from the field of cancer prevention and control will illustrate future potential directions for a translational health geography.

7.4 Translational Health Geography: Progress in Cancer Prevention and Control

Cancer research has benefited from a significant amount of attention from health geographers and others using geographic methodologies in recent years [10] [40]-[43]. Some of the more significant earlier efforts focused on breast cancer, after several breast cancer advocacy organizations in the early 1990's pioneered research into environmental pollutants and breast cancer risk. New evidence from animal models had suggested a possible link between breast cancer risk and mammary carcinogens and endocrine-disrupting compounds [44]. For example, the Long Island Breast Cancer Study Project (LIBCSP) was initiated in 1993 after breast cancer activist organizations were successful in winning Congressional legislation (Public Law 103-43) mandating the project [44]. Despite its origins in activism, however, grants

to fund the study were awarded to academic scientists, and so, some "activists sometimes felt shut out of the process" [44].

A second project emerged from a legislative mandate in Massachusetts for a breast cancer and environmental study after publication of data by the Massachusetts Department of Public Health about elevated breast cancer incidence on Cape Cod [44]. In order to bid for the research funds, Massachusetts activists founded the Silent Spring Institute. The Cape Cod Breast Cancer and Environment Study placed activists in governance roles. As described by Brody et al. [44], the first phase of the project involved GIS in the integration of cancer and environmental data and a search for patterns. The second phase of the project was a case-control study. Community members were updated and consulted throughout the project.

A third project is the Huntington Breast Cancer Action Coalition (HBCAC) breast cancer mapping project on Long Island. While this project was unique in its efforts to utilize mapping and community participation to investigate cancer, cancer information was not collected by a cancer registry on a continuous basis, but rather in a survey with a response rate of 37%. Finally, in my own work, the presentation of filtered maps of colorectal cancer in the tradition of Rushton's adaptive spatial filtering, supplemented by information on risk and preventive factors for colorectal cancer, enabled a community to organize and prioritize related experiences, thereby creating a future plan [45]-[47].

7.5 Conclusion: A Call for Translational Health Geography

In conclusion, translational health geography should investigate questions of health with emphases on the careful consideration of geographic scale and the translation of research findings into interventions to improve health. GIS

can facilitate investigation of scale, whereas community-engaged research approaches can facilitate the translation of research into intervention.

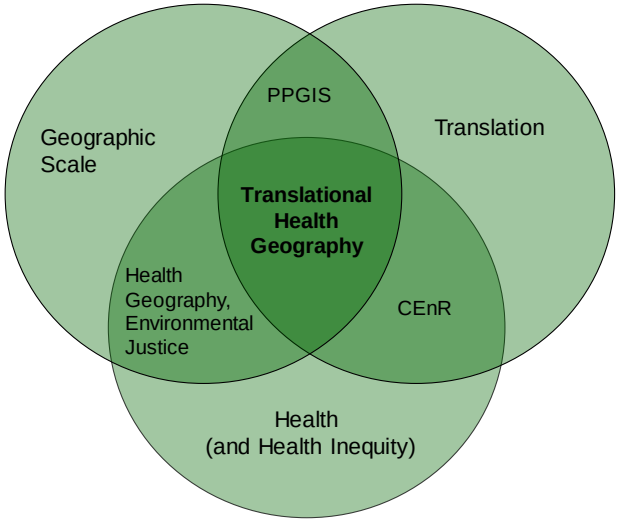

Figure 7.1 Schematic Translational Health Geography. (Color copy online.)

So far, however, the field of public participation geographic information systems (PPGIS) has had translation and scale at the forefront of investigations, but has largely neglected direct investigations of health. In contrast, the movement towards the use of community-engaged research approaches (CEnR) and related approaches for health disparities research has elevated questions of health and justice as well as the goal of translation at the forefront. These three literatures intersect in my opinion as in Figure 7.1, and so, the intersecting themes of (1) health, (2) scale as addressed by GIS, and (3) translation as addressed by participation should be the future foundation for translational health geography.

References

[1] K. S. McLeod, "Our sense of Snow: The myth of John Snow in medical geography," Social Science & Medicine, vol. 50, pp. 923-935, 2000.

[2] E. W. Gilbert, "Pioneer maps of health and disease in England," Geographical Journal, vol. 124, no. 2, pp. 172-183, 1958.

[3] A. Curtis and M. Leitner, Geographic Information Systems and Public Health: Eliminating Perinatal Disparity. IGI Global, 2006.

[4] S. Openshaw, The Modifiable Areal Unit Problem. Norwich, UK: Geo Books, 1983.

[5] H. E. Kurtz, "Scale frames and counter-scale frames: Constructing the problem of environmental injustice," Political Geography, vol. 22, pp. 887-916, 2003.

[6] M. Monmonier, How to Lie With Maps. Chicago, Ill: University of Chicago Press, 1991.

[7] P. O'Campo, "Invited commentary: Advancing theory and methods for multilevel models of residential neighborhoods and health," American Journal of Epidemiology, vol. 157, pp. 9-13, 2003.

[8] A. V. Diez Roux, "Invited commentary: Places, people, and health," American Journal of Epidemiology, vol. 155, pp. 516-519, 2002.

[9] A. V. Diez Roux and C. Mair, "Neighborhoods and health," Annals of the New York A. V. Academy of Sciences, vol. 1186, pp. 125-145, 2010.

[10] L. W. Pickle, L. A. Waller and A. B. Lawson, "Current practices in cancer spatial data analysis: A call for guidance," International Journal of Health Geographics, vol. 4, p. 3, 2005.

[11] S. Srinivasan, L. R. O'Fallon and A. Dearry, "Creating healthy communities, healthy homes, healthy people:

Initiating a research agenda on the built environment and public health," American Journal of Public Health, vol. 93, pp. 1446-1450, 2003.

[12] M. W. Leung, I. H. Yen and M. Minkler, "Community based participatory research: A promising approach for increasing epidemiology's relevance in the 21st century," International Journal of Epidemiology, vol. 33, pp. 499-506, 2004.

[13] T. R. Frieden, "A framework for public health action: The health impact pyramid," American Journal of Public Health, vol. 100, pp. 590-595, 2010.

[14] C. C. Branas and J. M. Macdonald, "A simple strategy to transform health, all over the place," Journal of Public Health Management and Practice," J.P.H.M.P., vol. 20, pp. 157-159, 2014.

[15] A. V. Diez Roux, "Investigating neighborhood and area effects on health," American Journal of Public Health, vol. 91, pp. 1783-1789, 2001.

[16] J. A. Patz, H. Frumkin, T. Holloway, D. J. Vimont and A. Haines, "Climate change: Challenges and opportunities for global health," J.A.M.A., vol. 312, pp. 1565-1580, 2014.

[17] M. Donohoe, "Causes and health consequences of environmental degradation and social injustice," Social Science & Medicine, vol. 56, pp. 573-587, 2003.

[18] S. M. Phillips, C. M. Alfano, F. M. Perna and R. E. Glasgow, "Accelerating translation of physical activity and cancer survivorship research into practice: Recommendations for a more integrated and collaborative approach," Cancer Epidemiology, Biomarkers & Prevention: A publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology, vol. 23, pp. 687-699, 2014.

[19] J. W. Elena, L. B. Travis, N. I. Simonds, C. B. Ambrosone, R. Ballard-Barbash, S. Bhatia, J. R. Cerhan, P. Hartge, R. S. Heist, L. H. Kushi, T. L. Lash, L. M. Morton, K. Onel, J. P. Pierce, L. L. Robison, J. H. Rowland, D. Schrag, T. A. Sellers, D. Seminara, X. O. Shu, N. E. Thomas, C. M. Ulrich and A. N. Freedman, "Leveraging epidemiology and clinical studies of cancer outcomes: Recommendations and opportunities for translational research," Journal of the National Cancer Institute, vol. 105, pp. 85-94, 2013.

[20] S. H. Woolf, "The meaning of translational research and why it matters," J.A.M.A., vol. 299, pp. 211-213, 2008.

[21] N. Lurie, "Health disparities – less talk, more action," New England Journal of Medicine, vol. 353, p. 727, 2005.

[22] R. B. Warnecke, A. Oh, N. Breen, S. Gehlert, E. Paskett, K. L. Tucker, N. Lurie, T. Rebbeck, J. Goodwin and J. Flack, "Approaching health disparities from a population perspective: The National Institutes of Health Centers for Population Health and Health Disparities," American Journal of Public Health, vol. 98, pp. 1608-1615, 2008.

[23] S. B. Thomas, S. C. Quinn, J. Butler, C. S. Fryer and M. A. Garza, "Toward a fourth generation of disparities research to achieve health equity," Annual Review of Public Health, vol. 32, pp. 399-416, 2011.

[24] K. Glanz, R. T. Croyle, V. Y. Chollette and V. W. Pinn, "Cancer-related health disparities in women," American Journal of Public Health, vol. 93, pp. 292-298, 2003.

[25] N. B. Wallerstein and B. Duran, "Using community-based participatory research to address health disparities," Health Promotion Practice, vol. 7, pp. 312-323, 2006.

[26] R. E. Sieber, "Public participation geographic information systems across borders," The Canadian

Geographer/Le Géographe canadien, vol. 47, pp. 50-61, 2003.

[27] R. E Malone, V. B. Yerger, C. McGruder and E. Froelicher, " 'It's like Tuskegee in reverse': A case study of ethical tensions in institutional review board review of community-based participatory research," American Journal of Public Health, vol. 96, pp. 1914-1919, 2006.

[28] R. Flowerdew, D. J. Manley and C. E. Sabel, "Neighbourhood effects on health: Does it matter where you draw the boundaries?" Social Science & Medicine, vol. 66, pp. 1241-1255, 2008.

[29] L. A. Waller and C. A. Gotway, Applied Spatial Statistics for Public Health Data. New York, NY: John Wiley & Sons, 2004.

[30] A. Gelman and P. N. Price, "All maps of parameter estimates are misleading," Statistics in Medicine, vol. 18, pp. 3221-3234, 1999.

[31] A. B. Lawson, Statistical Methods in Spatial Epidemiology. New York, NY: John Wiley & Sons, 2013.

[32] M. Merrick, "Reflections on PPGIS: A view from the trenches," URISA Journal, vol. 15, pp. 33-40, 2003.

[33] G. Rushton and P. Lolonis, "Exploratory spatial analysis of birth defect rates in an urban population," Statistical Medicine, Vol. 15, pp. 717-726, 1996.

[34] K. M. M. Beyer, C. Tiwari, and G. Rushton, "Five essential properties of disease maps," Annals of the Association of American Geographers, vol. 102, pp. 1067-1075, 2012.

[35] K. M. M. Beyer and G. Rushton, "Mapping cancer for community engagement," Prevention of Chronic Disease, vol. 6, p. A03, 2009.

[36] C. Tiwari and G. Rushton, "Using spatially adaptive filters to map late stage colorectal cancer incidence in

Iowa," in Developments in Spatial Data Handling, P. Fisher, Ed. Berlin Heidelberg: Springer, 2005, pp. 665-676.

[37] C. Tiwari and G. Rushton, "A spatial analysis system for integrating data, methods and models on environmental risks and health outcomes," Transactions in GIS, vol. 14, pp. 177-195, 2010.

[38] Q. Cai, G. Rushton and B. Bhaduri, "Validation tests of an improved kernel density estimation method for identifying disease clusters," Journal of Geographical Systems, vol. 14, pp. 243-264, 2012.

[39] K. A Matthews, "Iowa Cancer Maps 2.0: Colorectal cancer: Areas with persistently high/low rates of incidence, late-stage, and mortality (1999 to 2010)," Available from http://www.uiowa.edu/iowacancermaps2/colorectal.html (last accessed July 17, 2014).

[40] M. Ward, F. Ullrich, K. Matthews, G. Rushton, R. Tracy, D. F. Bajorin, M. A. Goldstein, M. P. Kosty, S. S. Bruinooge, A. Hanley and C. F. Lynch, "Access to chemotherapy services by availability of local and visiting oncologists," Journal of Oncology Practice / American Society of Clinical Oncology, vol. 10, pp. 26-31, 2014.

[41] G. Rushton, M. P. Armstrong, J. Gittler, B. R. Greene, C. E. Pavlik, M. M. West and D. L. Zimmerman, "Geocoding in cancer research: A review," American Journal of Preventive Medicine, vol. 30, pp. S16-S24, 2006.

[42] C. A. Brewer, "Basic mapping principles for visualizing cancer data using geographic information systems (GIS)," American Journal of Preventive Medicine, vol. 30, pp. S25-S36, 2006.

[43] K. A. Henry, X. Niu and F. P. Boscoe, "Geographic disparities in colorectal cancer survival," International Journal of Health Geography, vol. 8, p. 48, 2009.

[44] J. G. Brody, J. Tickner and R. A. Rudel, "Community-initiated breast cancer and environment studies and the precautionary principle," Environmental Health Perspectives, vol. 113, no. 8, pp. 920-925, 2005.

[45] K. M. M. Beyer, S. Comstock and R. Seagren, "Disease maps as context for community mapping: A methodological approach for linking confidential health information with local geographical knowledge for community health research," Journal of Community Health, 35, pp. 635-644, 2010.

[46] K. M. M. Beyer, S. Comstock, R. Seagren, and G. Rushton, "Explaining place-based colorectal cancer health disparities: Evidence from a rural context," Social Science & Medicine, vol. 72, pp. 373-382, 2011.

[47] C. K. Gwede, B. G. Ward, J. S. Luque, S. T. Vadaparampil, D. Rivers, D. Martinez-Tyson, S. Noel-Thomas and C. D. Meade, "Application of geographic information systems and asset mapping to facilitate identification of colorectal cancer screening resources," Online Journal of Public Health Informatics, vol. 2, No. 1, 2010.

Chapter 8

Spatial Analysis of Successful Aging in Older Adults based on Objective and Subjective Measures

Ellen K. Cromley

8.1 Introduction

Methodological approaches advocated by Dr. Gerard Rushton [1] for analyzing geocoded health data inform this study's explorations of geographical patterns of (un-)successful aging using individual-level data from a statewide survey of community-living older people in New Jersey. Successful population aging may be measured in a number of ways. Some measures, such as diagnosis of chronic conditions, are objective. Other measures are subjective, such as an individual's own assessment of how well he or she is aging. Global and local colocation quotients are used in this analysis to compare spatial patterns for the different measures of successful aging [2].

8.2 Successful versus Unsuccessful Population Aging

Population aging is a major unprecedented demographic process affecting every region of the world [3]. Rowe and Kahn [4] [5] have defined three objective criteria for successful population aging: The ability to maintain low risk of disease and disease-related disability; high levels of mental and physical health; and active engagement with life.

Researchers adopting these definitions tend to utilize objective criteria for measuring them from records or by self-report of chronic conditions including arthritis, hypertension and osteoporosis, or functional disability such as difficulty walking a specific distance, standing for two hours, or stooping. More recent studies have however examined the extent to which older adults perceive their own aging experience as successful.

Subjective criteria include individuals' own assessments of how well they are aging and how they rate their lives at present. Objective and subjective measures of success do not always agree. In one study comparing the two, an approximate one third of older adults with chronic conditions rated themselves as aging successfully, while a similar proportion of those without chronic conditions believed they were not aging well [6]. This study's research question in light of these types of differences is whether those differences vary geographically?

Analyzed data for this study were sampled from the ORANJ BOWL^{sm} (Ongoing Research on Aging in New Jersey – Bettering Opportunities for Wellness in Life) panel of 5,688 adults who completed interviews between November, 2006 and April, 2008. Included participants were between the ages of 50 and 74, lived in New Jersey, and were able to participate in a one-hour English-language telephone interview. Panel members were recruited by telephone cold-calling using list-assisted random-digit-dialing (LA-RDD) procedures.

Coverage of residential POTS numbers for sample population represented by the panel's sample is estimated at 95%. Comparison of ORANJ BOWL respondent characteristics with those of all persons aged 50 to 74 years-old living in New Jersey reveals similar racial composition, rates of being born in the state, and marital status. The

ORANJ BOWL sample has a slightly higher proportion of females (63.7% to 53.3%) and a slightly higher percentage of individuals with advanced secondary degrees (18.5% to 14.8%). It under-represents persons of Hispanic descent, since participants were restricted to those fluent in English. A two-factor model of successful aging is developed in this study for a classification of every participant as aging successfully or not on objective or subjective measures [7].

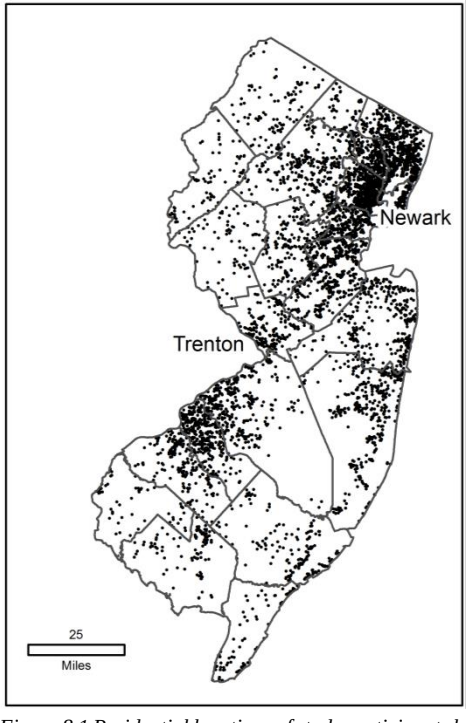

Figure 8.1 Residential locations of study participants by block centroid.

8.3 Appropriate Use of Individual-level Geocoded Data

The U.S. federal government estimates today that 80% of health records are geocoded, a significant increase over the last several decades. Yet, access to this type of data is still not assured. In Connecticut, for example, the Tumor Registry, one of the oldest in the country, provides access to data only at the census tract level, owing to concerns about privacy and confidentiality. For the research presented in this article, data on survey residential locations were available at the census block level, but not for the individual residence of 98% of participants (Figure 8.1). Rushton has been an advocate for use of individual-level geocoded health data, based on his research using geographic data to study cancer [1]. Especially important in this work were the techniques to ensure the suitability of such data for geographic analysis.

8.4 Innovative Use of Spatial Statistical Methods and Spatially Adaptive Filters

In seeking to explore patterns of health and disease in local populations, Rushton also advocated the use of spatially adaptive filters [8]. The method selected to investigate patterns of successful and unsuccessful aging in older adults incorporates spatially adaptive filters in assessment of colocation. Colocation refers to the degree of spatial association between categories in a population. Many geographic databases are of this type, such as, different types of 'populations' of retail establishments, crimes, health outcomes including cancers or respiratory conditions, or plants. In the research on successful aging, we were seeking to understand whether older adults in different categories of

successful or unsuccessful aging are more or less likely to be located near to each other than expected?

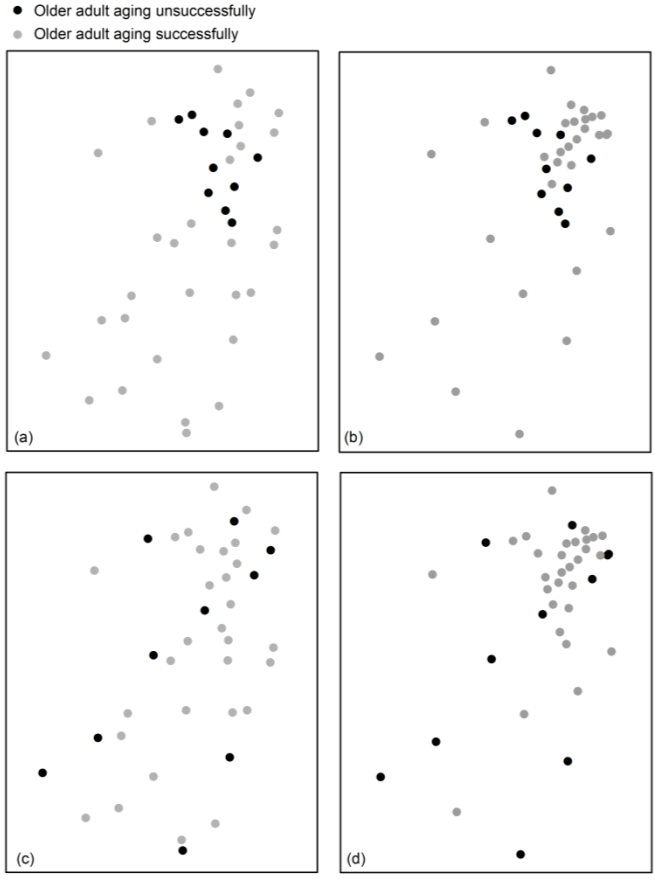

Figure 8.2 Hypothetical patterns of colocation of unsuccessful and successful agers.

For example, in each of four schematic examples in Figure 8.2, we imagine 40 adults, 30 of whom have aged successfully and 10 of whom have aged unsuccessfully. Note, regardless of the population distribution, unsuccessful agers

may be more highly colocated with other unsuccessful agers in Figure 8.2(a) and Figure 8.2(b). Or they may be more highly colocated with other successful agers in Figure 8.2(c) and Figure 8.2(d).

To statistically measure spatial patterns of colocation, we used both global [9] and local [10] colocation quotients (CLQs) for objective and subject measures of successful aging. Then, for the group of survey participants who aged successfully on both measures, we assessed the difference in their local colocation quotients with unsuccessful agers on objective and subjective measures. Gaussian weights were used for the global and the local analyses. A spatially adaptive filter identifying 100 nearest neighbors was used.

8.5 Spatial Patterns of (Un-)Successful Aging

Most adults in the survey (73%) were aging successfully on both objective and subjective measures. Less than 10% of adults in the survey (8.3%) were not aging successfully on both measures. Some participants would be considered aging successfully on one measure, with a slightly higher proportion aging successfully on the subjective measure (10%) than on the objective measure (8.6%). The global colocation quotients for participants in different categories of aging show that, in terms of the objective measure, adults not aging successfully are somewhat more likely to have other adults not aging successfully as their neighbors (CLQ = 1.06). Otherwise, the level of colocation is very close to expected. On the subjective measure of successful aging, both unsuccessful and successful agers are somewhat more likely to have unsuccessful neighbors than expected, with CLQs slightly greater than unity.

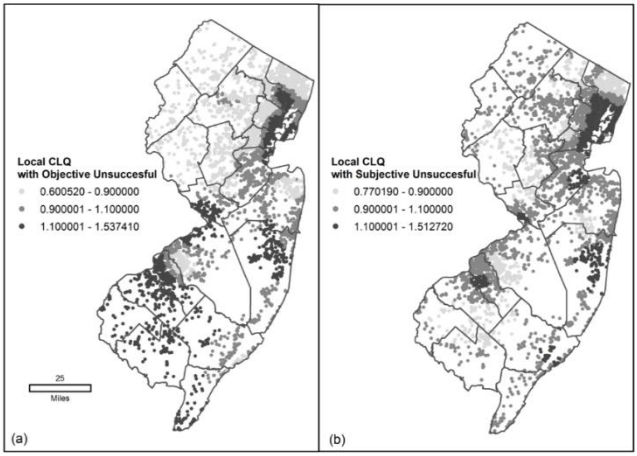

Figure 8.3(a) Older adults who aged successfully on the objective measure of aging; and Figure 8.3(b) Older adults who aged successfully on the subjective measure of aging.

The local CLQs show strong regional variation in the patterns of colocation of successful and unsuccessful agers. Figure 8.3(a) shows the locations of 4,456 older adults aging successfully on objective measures and their local colocation with older adults aging unsuccessfully on objective measures (who are not mapped). Individuals living near Newark, Trenton, and the southwestern counties of the state are more likely to have older adults in their midst who were not aging successfully based on objective criteria. In Bergen County in northeastern New Jersey and three counties (Warren, Hunterdon, and Somerset) in the northwestern part of the state, older adults who aged successfully on objective measures are much less likely to have neighbors who were aging unsuccessfully based on these measures. For the 4,632 older adults who aged successfully based on subjective criteria in Figure 8.3(b), individuals living near Newark are more likely to have older adults in their local areas who were not aging successfully based on subjective criteria.

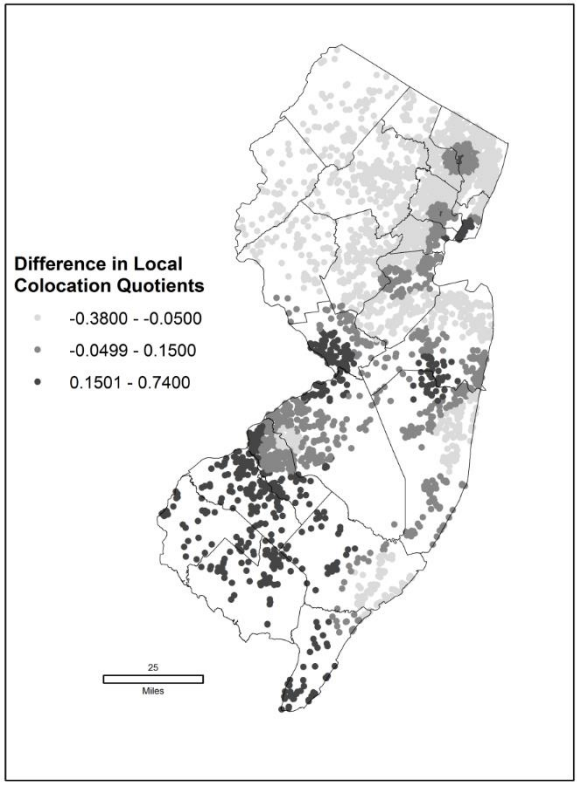

Figure 8.4 Difference in local colocation coefficients.

Finally explored are spatial differences for the 4,076 participants who aged successfully on both subjective and objective dimensions. Their local colocation quotient measuring spatial association with subjectively unsuccessful agers was subtracted from their local colocation quotient measuring spatial association with objectively unsuccessful agers (Figure 8.4). This map shows a strong regional pattern. In northern New Jersey and along the southeast coast, successful agers on both dimensions were more likely to be colocated with unsuccessful subjective agers (as the

difference is negative). In southern New Jersey, especially in the southwest in Gloucester, Salem, and Cumberland counties, successful agers on both dimensions were more likely to be colocated with unsuccessful objective agers (as the difference is positive).

8.6 Discussion and Conclusion

Older individuals not aging successfully are more likely to be colocated in some regions and communities in the study area. This strong evidence of local colocation is however different depending on whether the measure of successful aging is objective or subjective. These patterns reveal communities where older adults are more positive about their own aging experiences than are indicated by their objective health problems.

Age and gender were associated with objective but not subjective measures of success in aging in the study population as a whole. Older survey participants and women reported more chronic conditions than younger participants and men. Note there were no statistical differences in the age and gender composition of the regions in northeast and southwest New Jersey than in the state as a whole.

Further research will focus on three main questions. First, are the effects of objective limitations mitigated by the environment? If older people live in automobile environments with detached houses that do not require them to go up and down steps, their possible inabilities to walk or handle stairs may not be perceived as functional limitations.

Second, do shared community norms affect individuals' views of how successfully they are aging? Research into social networks and aging [11] provides a foundation for this line of inquiry.

Third, what explains resilience? We can identify individuals who are aging successfully, and yet are colocated with older adults who are not aging successfully. How are the successful individuals different from nearby residents? To explore these questions fully, we would need data on the panel over time.

Acknowledgments

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References

[1] G. Rushton, M. P. Armstrong, J. Gittler, B. R. Greene, C. E. Pavlik, M. M. West and D. L Zimmerman, Geocoding Health Data: The Use of Geographic Codes in Cancer Prevention and Control, Research, and Practice. Boca Raton, Florida: CRC Press Taylor & Francis Group, 2008.

[2] E. K. Cromley, M. Wilson-Genderson, Z. Christman and R. A. Pruchno, "Colocation of older adults with successful aging based on objective and subjective measures," Journal of Applied Geography, vol. 56, pp. 13-20, 2015.

[3] United Nations, Department of Economic and Social Affairs, Population Division, World Population Ageing

2013. ST/ESA/SER.A/348. New York, NY: United Nations, 2013.

[4] J. W. Rowe and R. L. Kahn, "Human aging: Usual and successful," Science, vol. 237, pp. 143-149, 1987.

[5] J. W. Rowe and R. L. Kahn, Successful Aging. New York, NY: Pantheon, 1998.

[6] W. J. Strawbridge and M. I. Wallhagen, "Self-rated successful aging: Correlates and predictors," in Successful Aging and Adaptation with Chronic Diseases in Older Adulthood, L. W. Poon, S. H. Gueldner and B. M. Sprouse, Eds. New York, NY: Springer, 2003, pp. 1-24.

[7] R. A. Pruchno, M. Wilson-Genderson and F. P. Cartwright, "A two-factor model of successful aging," Journal of Gerontology: Psychological Sciences, vol. 65, pp. 671-679, 2010.

[8] Q. Cai, DMAP IV User Manual. Iowa City, IA: Department of Geography, University of Iowa, 2007.

[9] T. F. Leslie and B. J. Kronenfeld, "The colocation quotient: A new measure of spatial association between categorical subsets of points," Geographical Analysis, vol. 43, pp. 306-326, 2011.

[10] R. G. Cromley, D. M. Hanink and G. C. Bentley, "Geographically weighted colocation quotients: Specification and application," The Professional Geographer, vol. 66, pp. 138-148, 2014.

[11] N. A. Christakis and J. H. Fowler, "Social contagion theory: Examining dynamic social networks and human behavior," Statistics in Medicine, vol. 32, pp. 556-577, 2013.

Chapter 9

Do International Medical Graduates (IMGs) Improve Spatial Access to Physicians? Rushton's Locational Analysis Framework in Practice

Sara McLafferty, Avijit Ghosh and Jamie Fishman

9.1 Internationally-trained Primary Care Physicians and Access to Primary Care

Primary care physicians (PCPs) are critically important components of health care systems, providing preventive, diagnostic and routine care, and serving as gateways to more specialized health services. Wide disparities exist in the geographical availability of PCPs in the United States, as they are less available in rural areas than in urban areas – and within cities, they are in short supply in certain low-income and minority neighborhoods [1] [2]. To redress these rural-urban and intra-urban inequalities in primary care, the U.S. admits to its medical residency programs, significant numbers of international medical graduates (IMGs) who boost the overall supply of physicians. Currently more than 200,000 IMGs practice in the U.S., representing one-quarter of the physician workforce. International medical graduates completed their training at medical schools outside the U.S. Even though the majority of IMGs who practice in the U.S. are immigrants, a growing proportion (currently 38.5% of the IMG applicant pool) consists of American citizens who obtained their medical training overseas [3].

IMGs may impact the uneven geographical distribution of physicians if they enter the country under a visa program that incentivizes them to practice in under-served areas [4]. Immigration programs like the Conrad 30 Waiver Program attempt to assign IMGs to underserved areas. These programs, for example, offer waivers of medical residency requirements for IMGs who agree to practice for a certain length of time in areas designated as Health Professional Shortage Areas (HPSAs) and Medically Underserved Areas (MUAs). In addition, states have their own medical licensure requirements for IMGs that may influence IMGs' location decisions [5].

Many studies have investigated the impacts of IMGs on geographic inequalities in availability of primary care physicians. Research with respect to rural-urban inequalities shows that IMGs are more likely than US-trained physicians to practice in high-need and under-served regions [6]-[9]. At the same time, studies show that IMGs are more likely than US-trained physicians to locate in areas of high physician supply [8], a seemingly contradictory finding. The channeling of IMGs to both high- and low-physician supply areas suggests not only the presence of cohorts of IMGs with distinct location decisions, but also the occurrence of time-dependent IMG migration flows from shortage areas to surplus areas.

Most existing work on IMG locations emphasizes regional and national variations: Less attention has been paid to the locations of IMGs within cities and the implications for inequalities in spatial access to services. One of the few urban studies [10] found that IMGs in cities were disproportionately located in high-poverty areas, although there was considerable variation among cities. In general, research on IMG locations has been limited by its focus on the geographic patterns of IMGs while neglecting the processes of location

and migration that give rise to those patterns. Mutual dependencies between providers' and consumers' spatial behaviors, and the resulting effects on service location and access are central themes in Dr. Gerard Rushton's research. We revisit these themes in our study of IMG locations and locational change in Chicago.

9.2 Rushton's Contributions to Locational Analysis

Effects of the spatial organization of economic and social activities on individuals' decision-making and well-being have been a key focus of Rushton's research. He examined in his early work how the locations of retail and service facilities influenced the use of those facilities, demonstrating the interdependencies between behavior and locational context [11]. He also spearheaded advances in location-allocation modeling that were used to evaluate inequalities in access, and to identify more effective locational arrangements that may reduce the distances and times for traveling to reach essential service facilities [12] [13]. Underpinning this work was the recognition that location matters: People's ability to use services depends critically on where services are located. Hence, location planning and analysis are essential for reducing the disparities in access that exist among populations and places.

In his writings on central place theory, Rushton modelled the spatial organization of retail and service firms as the outcome of firms' and consumers' interlocking spatial decisions [14]. The location decisions made by providers reflected their assessments of local population and market potential, while consumer decisions about where to obtain services considered the spatial accessibility of service outlets and the interplay of personal, household, and service constraints. Similarly, Rushton's locational models for

publicly-provided services hypothesized providers' and consumers' decision-making as interdependent, even while providers' locational decisions might also result from administrative rules embedded in political structures [15]. For example, in analyzing regional planning of health services in rural India, he demonstrated that the planning process relied on administrative assumptions about the allocation of services among districts that often produced suboptimal location decisions [16].

Rushton's approach to locational analysis relied critically on geospatial data. In the 1970s and early 1980s at a time when the term geographic information system (GIS) was not widely known, he constructed large spatial databases on populations, towns, transportation networks, service centers, and other place characteristics in the state of Iowa and rural India. With limited computing resources, he created rudimentary geographic information systems for analyzing spatial accessibility and locational efficiency. Teams of his students (including two of this study's authors) collected and managed geospatial data; created distance matrices to represent spatial relationships; and coded computer programs to perform spatial analyses and location-allocation modeling. These were among the first steps towards Rushton's vision of developing spatial decision support systems for regional development and public health planning.

The two themes of spatial access to services, and geospatial data and methods provide the framework for the research presented here. Our investigation focuses on geographic inequalities in access to primary care physicians (PCPs) in the Chicago metropolitan area, and it utilizes geospatial data and spatial analysis methods popularized by Rushton in addressing the research problem. Our specific research question is whether internationally-trained primary care physicians locate in neighborhoods where PCPs are in

short supply and thus reduce disparities in access to primary care.

9.3 Data and Methods

Our dynamic approach to analyzing the uneven locations of primary care physicians involves tracking movements of IMGs and U.S.-trained PCPs over time in Cook County, Illinois. We rely on data from the American Medical Association's Physician Masterfile for 2000 and 2008 to evaluate PCP locations. Our database includes information about all physicians who are members of the AMA, and it represents a near-complete sample of all physicians. Physicians who were retired or not actively practicing were removed from the database for each year. Only office-based physicians were retained. Physicians whose specialties include general practice, family medicine, and internal medicine were identified as PCPs.

This study uses a geocoding process for physician practice locations. Note the benefits and pitfalls of geocoding health data are discussed in detail in Rushton's work on geocoding of cancer data [17]. Each physician record in the database includes two types of locational information, namely, the physician's office address and mailing address. More than 90 percent of the PCPs had an office address and were geocoded to that location. For remaining physicians, the mailing address was geocoded even though this may introduce bias if a mailing address is not an actual office location [18].

The database also includes basic demographic information about the physician and the name of his or her medical school. We used the latter to identify international medical graduates as physicians trained at a medical school outside the U.S. In 2008, 2,615 of the 5,900 PCPs in Cook

County (42.3%) were IMGs. Each physician in the database has a unique code number for tracking if he or she moves from one office to another through time. We used these codes to study and compare shifts in office locations from 2000 to 2008 for IMGs and US-trained PCPs.

First and foremost, a measure of spatial access to service is required for inferring the impact of IMG locations on overall spatial inequalities in access to PCPs. To create the spatial access measure, we used kernel estimation, a widely used spatial filtering method, wherein spatial access is assumed to vary continuously over space rather than being based on geographic zones, such as zip codes or census tracts. Rushton pioneered the implementation of spatial filtering methods in research on health disparities [19] [20]. Our method creates a smooth, continuous surface map of spatial access to PCPs, as measured by the physician-to-population ratio. Peaks on the map indicate areas of high spatial access (high physician-to-population ratio) and valleys show areas of poor spatial access.

A key component of spatial filtering is the bandwidth, and this is the geographic extent or radius of the spatial filter for determining the local density of events. Populations with car access were assigned an 8 km bandwidth, while those without car access were assigned a 3 km bandwidth to represent their more limited geographic mobility. These values are derived from empirical studies of travel patterns within cities in North America [21], although we acknowledge that people's actual travel patterns may be more complex and variable than can be depicted by fixed radii. Population counts for the car and non-car subpopulations were extracted by census block from the American Community Survey, and kernel estimation was used to determine local population density based on the respective bandwidth. An overall index of local spatial access to PCP

services was obtained by computing the weighted average of the respective physician-to-population ratios for car and non-car populations at each location. We computed this index for each study year of 2000 and 2008, based on PCP data for that year. We refer to this smoothed physician-to-population ratio as the 'spatial access index', and use it for assessing variations in local spatial accessibility of PCPs across Cook County.

In addition to the smoothed physician-to-population ratio, we employed two government-defined measures of physician underservice: Health Professional Shortage Areas (HPSAs) and Medically-Underserved Areas. (MUAs). The federal government defines these areas from multiple criteria including socioeconomic indicators of population need for health services, and the availability of physicians compared to population within the census tracts comprising a HPSA or MUA. Criteria differ between the two types of designated shortage areas [22]. It is important to note that shortage area boundaries are infrequently updated, and so, the districts do not necessarily reflect current population characteristics and physician supply.

The map of smoothed physician-to-population ratio for 2008 (Figure 9.1) shows wide inequalities in overall spatial access to primary care physicians in Cook County. Areas of high physician supply are located in and near downtown Chicago and in urban and suburban areas north and west of downtown. In contrast, Chicago's South Side and southeastern suburbs are areas of low physician supply and thus have poor spatial access to PCPs. These disparities closely follow patterns of socioeconomic and racial segregation, with low-income areas and areas of high African-American concentration experiencing low spatial access. As in many other U.S. cities, primary care physician shortages are closely aligned with racial and socioeconomic disadvantage [23].

9.4 Results

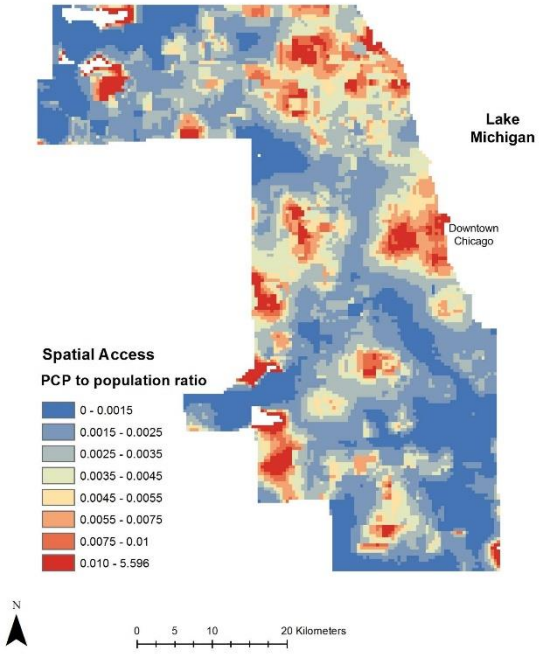

Figure 9.1 Spatial access to primary care physicians in Cook County, IL in 2008. Values represent physician-to-population ratios (PCPs per 100,000 population) determined via kernel estimation and incorporating access to automobile transportation.
(Color copy online.)

In 2008, internationally-trained medical graduates accounted for almost one-half (42%) of Cook County's primary care physicians, indicating their overall importance for local physician supply. Similarly to their US-trained counterparts, IMG PCPs were unevenly distributed across the county, with high concentrations in and around downtown Chicago and in neighborhoods north and west of downtown.

However, based upon the calculated 2008 spatial access index in Figure 9.1 at each PCP office location, IMGs practiced in locations with a lower average spatial access index value (103.17 physicians to 100,000 population) than did US-trained PCPs (141.83), indicating that IMGs tend to work in areas of lower PCP supply. IMGs were also more likely than US-trained PCPs (20% vs 11%) to practice in federally-designated Health Professional Shortage Areas. These results offer preliminary support for the hypothesis that IMGs fill in the gaps by practicing in areas where PCPs are in short supply; and this result is based on both our index of spatial access and federally-defined health care shortage areas.

Nevertheless, the geographical distribution of PCPs in any year is the product of dynamic processes of settlement and mobility as physicians decide not only where to practice but also whether or not to shift their practice's location over time. Based on location data for 2000 and 2008, we categorized PCPs into four groups: 1) Stable – physicians whose office locations did not change over time; 2) Movers – physicians whose office location shifted within the study area from 2000-2008; 3) Entrants – PCPs who entered the study area between 2000 and 2008; 4) Exits – PCPs who left the study area between 2000 and 2008.

In the case of entrants, odds ratios reveal that IMGs have higher odds than do US-trained PCPs of locating in an area where PCPs are undersupplied as defined by our spatial access index (IMG: 0.15 vs. US-trained: 0.12) or by the federal government's designated physician shortage areas, HPSAs (0.251 vs. 0.140) and MUAs (0.93 vs. 0.63) in 2000. Thus, IMGs who enter the region are more likely than their US-trained counterparts to locate in an underserved area.

Even so, the odds ratios for both groups are well-below unity, indicating an overall tendency towards not locating in

poorly served areas. In fact, both IMGs and US-trained PCPs are more likely to locate outside a HPSA than inside one, and similarly for MUAs. In addition, both groups are significantly less likely to choose a location characterized by the poorest spatial access – defined here as having a spatially-smoothed ratio of fewer than 50 PCPs per 100,000 population [22] – than a more well-supplied location. Our demonstration of locational avoidance of underserved areas by entering PCPs suggests their initial location decisions reinforce spatial inequalities in access.

In the case of movers, we compared the spatial access index values at the origin and destination office locations to assess trends in PCP migration. Results show that both IMGs and US-trained PCPs tend to relocate within areas of moderate or high spatial access; or to move from areas with lower spatial access to those with higher spatial access. For both groups, a majority of PCPs who were located in a high spatial access area in 2000 moved to another high access location in 2008 (53% IMGs and 64% US-trained). Similarly, the vast majority of PCPs who relocated from a medium spatial access area, moved to an area with similar or higher spatial access (94% IMGs and 98% US-trained). Only a handful of PCPs relocated into areas of low spatial access, and most of them moved from one low access neighborhood to another. Only 2.1% of US-trained physicians and 3.8% of IMGs who relocated from a high access area moved to a low access area. Thus, relocation processes of both domestically- and internationally-trained PCPs tend to reinforce inequalities in spatial access when physicians move into areas that are already well-endowed with primary care doctors.

9.5 Conclusion

Our findings show that in Cook County, internationally-trained PCPs fill in the gaps in basic health care for potential patients to a modest degree, especially in their initial location choices. Over time, however, their location decisions mirror those of their domestically-trained counterparts, maintaining wide gaps in spatial access to PCP services. Even though IMGs are slightly more likely than domestically-trained PCPs to locate in areas of physician shortage, there is a persistent migration of both groups from areas of low supply to areas with relatively more PCPs. These results are consistently similar for three indicators of local physician supply, namely, HPSAs, MUAs and our spatially-smoothed physician to population ratios. These results therefore raise questions about the long-term effectiveness of policies that encourage PCPs to locate in physician shortage areas.

Several decades ago, Rushton put forth a vision for locational analysis that emphasized using geospatial data and methods to map and understand geographical inequalities in access to essential services. In his view, locational decisions by service providers and consumers resulted in an uneven landscape characterized by both spatial and social disparities in service supply and access. Our research on primary care physicians in Cook County illustrates and builds on these themes. Geospatial data and methods were critically important in generating our findings, confirming Rushton's observation that locational analysis research rests on a strong geospatial data foundation. Today, vast computing resources coupled with GIS and 'big' geospatial data enable sophisticated locational analyses of access to essential health and social services over time and space. Our work on primary care physicians just scratches the surface of this dynamic research field.

Acknowledgment

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References

[1] M. Guagliardo, "Spatial accessibility of primary care: Concepts, methods and challenges," International Journal of Health Geographics, vol. 3, no. 1, p. 3, 2004.

[2] T. C. Ricketts and R. Randolph, "Urban-rural flows of physicians," The Journal of Rural Health, vol. 23, no. 4, pp. 277-285, 2007.

[3] N. L. Eckert and M. van Zanten, "U.S.-citizen international medical graduates – A boon for the workforce?" New England Journal of Medicine, vol. 372, no. 18, pp. 1686-1687, 2015.

[4] G. Traverso and G. T. McMahon, "Residency training and international medical graduates: Coming to America no more," J.A.M.A., vol. 308, no. 21, pp. 2193-2194, 2012.

[5] B. Peterson, S. Pandya and D. Leblang, "Doctors with borders: Occupational licensing as an implicit barrier to high skill migration," Public Choice, vol. 160, no. 1-2, pp. 45-63, 2014.

[6] M. A. Fordyce, M. P. Doescher, F. M. Chen and G.L. Hart, "Osteopathic physicians and international medical graduates in the rural primary care physician workforce," Family Medicine-Kansas City, vol. 44, no. 6, p. 396, 2012.

[7] L. G. Hart, S. M. Skillman, M. Fordyce, M. Thompson, A. Hagopian and T. R. Konrad, "International medical graduate physicians in the United States: Changes since

1981," Health Affairs, vol. 26, no. 4, pp. 1159-1169, 2007.

[8] S. Mick, S. Y. D. Lee and W. Wodchis, "Variations in geographical distribution of foreign and domestically trained physicians in the United States: 'safety nets' or 'surplus exacerbation'?" Social Science & Medicine, vol. 50, no. 2, pp. 185-202, 2000.

[9] M. J. Thompson, A. Hagopian, M. Fordyce and L. G. Hart, "Do international medical graduates (IMGs) 'fill the gap' in rural primary care in the United States? A national study," The Journal of Rural Health, vol. 25, no. 2, pp. 124-134, 2009.

[10] S. Mick and S. Y. D. Lee, "International and US medical graduates in US cities," Journal of Urban Health, vol. 76, no. 4, pp. 481-496, 1999.

[11] G. Rushton, "Postulates of central-place theory and the properties of central-place systems," Geographical Analysis, vol. 3, no. 2, pp. 140-156, 1971.

[12] A. Ghosh and G. Rushton, Spatial Analysis and Location-Allocation Models. New York, NY: Van Nostrand Reinhold Co., 1987.

[13] G. Rushton, "Use of location-allocation models for improving the geographical accessibility of rural services in developing countries," International Regional Science Review, vol. 9, no. 3, pp. 217-240, 1984.

[14] G. Rushton, "Behavioral correlates of urban spatial structure," Economic Geography, vol. 47, no. 1, pp. 49-58, 1971.

[15] G. Rushton, "The Roepke Lecture in Economic Geography: Location theory, location-allocation models, and service development planning in the Third World," Economic Geography, vol. 54, no. 2, pp. 97-120, 1988.

[16] H. B. Fisher and G. Rushton, "Spatial efficiency of service locations and the regional development process,"

Papers in Regional Science, vol. 42, no. 1, pp. 83-97, 1979.

[17] G. Rushton, M. Armstrong, J. Gittler, D. Greene, C. Pavlik, M. West and D. Zimmerman, "Geocoding in cancer research: A review," American Journal of Preventive Medicine, vol. 30, no. 2, pp. S16-S24, 2006.

[18] S. McLafferty, V. Freeman, R. Barrett, L. Luo and A. Shockley, "Spatial error in geocoding physician location data from the AMA Physician Masterfile: Implications for spatial accessibility analysis," Spatial & Spatiotemporal Epidemiology, vol. 3, pp. 31-38, 2012.

[19] G. Rushton, "Public health, GIS, and spatial analytic tools," Annual Review of Public Health, vol. 24, pp. 43-56, 2003.

[20] G. Rushton and P. Lolonis, "Exploratory spatial analysis of birth defect rates in an urban population," Statistics in Medicine, vol. 15, pp. 717-726, 1996.

[21] L. Bissonnette, K. Wilson, S. Bell and T. I. Shah, "Neighbourhoods and potential access to health care: The role of spatial and aspatial factors," Health and Place, vol. 18, no. 4, pp. 841-853, 2012.

[22] T. C Ricketts, L. Goldsmith, G. Holmes, R. Randolph, R. Lee, D. Taylor and J. Ostermann, "Designating places and populations as medically underserved: A proposal for a new approach," Journal of Health Care for the Poor and Underserved, vol. 18, pp. 567-89, 2007.

[23] M. Guagliardo, C. Ronzio, I. Cheung, E. Chacko and J. Joseph, "Physician accessibility: An urban case study of pediatric providers," Health and Place, vol. 10, no. 3, pp. 273-283, 2004.

V. Abstracts of Additional Papers

The final chapter has the abstracts of papers of six remaining former students, listed in alphabetical order, who either presented at the one-day symposium, or would have presented if they had been able to attend it or the two special sessions.

Chapter 10

Abstracts of Additional Papers:

Beyond Euclidean Maps: Simultaneous Thinking, Networks and Rushton's 'Leitwissenschaft' (a leading or guiding science)

Rudy Banerjee

Gerard Rushton developed a pioneering effort in geographic thought that has been under-identified in the field. However, developments in operations research and complexity science are providing evidence of his insights within a wider framework in geography. Ever since his publication of simultaneous effects on central places, which invalidates the neat geometric primitives of one-at-a-time sequential process of central places, location science has tackled the complexities of real world processes that are neither 'central' nor 'places' nor Euclidean but have a combination of behavior, space and environmental interactions. The simultaneous considerations required to tackle such complex dynamics were recognized early on by Rushton, and these have continued to affect not only location science but also epidemiology, GIS, health geography and economic geography.

In this presentation, I will provide a series of examples on how Rushton challenged the sequential hypothesis in geographic problem solving, and applied the

simultaneous thought process that is evident in complexity science and recognized in operations research as the basis for optimal solutions. I will review his pioneering efforts in Medical Geography, especially the paper: Rushton, G. and P. Lolonis (1996), "Exploratory spatial analysis of birth defect rates in an urban area," Statistics in Medicine 15, 717-726. Here, he applies the simultaneous thinking paradigm, adapting his post-central place approach, to solidify what I would label as Rushton's 'Leitwissenschaft' (a leading or guiding science).

Spatial Filter Method for Disease Cluster Detection, beginning with Gerard Rushton's 1996 article entitled, Exploratory spatial analysis of birth defect rates in an urban area

Qiang Cai

Rushton published the aforementioned paper in Statistics in Medicine in 1996, and it has become a highly influential paper, cited 180 times to date. The paper introduced the spatial filter method with three key components: A fine resolution regular lattice of grid points to cover the study area; fixed distance circles around each grid point as basic units for disease rate estimation; and Monte Carlo simulation to test the statistical significance of disease rates at the grid points.

I based my dissertation research entitled, Mapping Disease Risk Using Spatial Filtering Methods, on his 1996 paper with several extensions. I extend regular grid points to variable grid points; fixed distance circles to spatially adaptive circles; and the Monte Carlo test to include calculations of power and false discovery rate.

Software (DMAP IV) was developed to implement the extensions of the original spatial filter method. A recent publication by Cai and Rushton summarizes these new developments of the spatial filter method, in "Validation tests of an improved kernel density estimation method for identifying disease clusters", Journal of Geographical Systems, 2012.

Spatial Efficiency of Central Place Systems under the Manhattan Metric

Panos Lolonis

This paper analyzes systematically the spatial efficiency of indicative types of central place systems that are commonly discussed in the Central Place Theory (CPT) literature. The analysis is centered on two interlinked concepts that have marked Rushton's research work, namely, spatial efficiency and distance travelled to service centers. Particular emphasis is placed on measuring the decrease in spatial efficiency, as defined by Fisher and Rushton (1979), in typical arrangements of central places and service areas by adopting the Manhattan metric as opposed to the Euclidean metric. Analyses are at a theoretical level, keeping most CPT assumptions constant in order to illustrate the magnitude of spatial inefficiencies introduced by the Manhattan metric and to highlight certain irregularities that are expected to arise in the provision of services and goods under certain special cases. The functional forms and the spatial efficiency values have been computed for several typical cases. The underlying goal of this work is to determine whether the Manhattan-like transportation networks observed in the real world act as a distorting factor in central place systems and inhibit us from testing the functioning of CPT mechanisms in reality.

Right Choice of Choice, Wrong Choice Timing: Gerry Rushton moved on too soon?

Jordan Louviere

Gerard Rushton introduced me to modeling choices. The UMTA transportation planning course introduced me to econometric choice models. I studied psychology to better understand why and how people choose. A chance encounter off the coast of Fiji led me to MIT and Dan McFadden's group, and I eventually taught in the MIT summer choice modeling course for 23 years. By that time Gerry had chosen to move on.

I was invited to Australia in 1977 to help setting airfares for Qantas, which led me to integrate: (1) Information Integration Theory and Conjoint Measurement; (2) probabilistic discrete choice models; (3) discrete multivariate analysis for contingency tables; and (4) experimental design methods that evolved into discrete choice experiments. I have worked in this area since then.

I have consistently worked on external validity, and I moved out of psychology due to a lack of interest in relating the theory and methods with what real people do. The Arrow-Solow Committee invited me to address the 1994 Conference on the Future of Contingent Valuation. I have since worked in applied economics, and my work has had global impact on non-market valuation.

Gerry's interest in the method of paired comparisons and MDS kindled a life-long interest in measurement. I became convinced that only theory-based measures were scientifically useful, and eventually developed a measurement method known as Best-Worst Scaling

(BWS). Tony Marley I and others have spent over a decade on the theoretical underpinnings of BWS, with a book published in 2015 by Cambridge University Press.

I returned to my roots in individual preferences and choices in 2003 using BWS as a way to study and model single individuals' behaviors. New estimation methods insure model convergence for single individuals, which we are applying to model individual wheat buyers in several countries to understand how wheat characteristics influence their choices, which should lead to better crop selection and planting choices by farmers. Finally, thanks to funding from SSHRC, Tony Marley, Towhidul Islam and I are extending the study of discrete choice to quantity choices (2 of X, 4 of Y, none of the rest) and testing the resulting data and models against actual purchases from the same people provided by a major panel company.

So, thanks to Gerry's inspiration and guidance, I am still working on choices, including pioneering some new and innovative ways to think about and model the choices that people make.

On Structures, Agency and Chance: Reflections on the Advisor-Student Relationship

John Mercer

The relationship between faculty advisors and graduate students is complex, involving the structures of higher education, institutions and disciplines, as well as the actions of both advisor and student. Chance is always present in the interaction. I explore this relationship through the geographical and historical narrative of two agents: Gerard Rushton as the advisor, and myself as the student.

Advisors shape the intellectual and career development of their students as well as recommend the research pathways that can last a lifetime. They are typically crucial role models. For me, the first of these two capacities was the more important, although Rushton had a lasting influence on my general methodologies, such as working with large data sets, but less so in terms of specific research questions or agendas.

We met by chance at McMaster University in 1964, this being Rushton's first academic appointment. I was a new master's student who was committed at that time to return to the UK for the Ph.D. degree. Though not my primary advisor, he soon changed my thinking and actions with dramatic effect, thereby converting me into a North American geographer rather than a British geographer. He literally changed my life. His course on location theory, advice on my housing research, and wider conversations led to my becoming a scientific geographer,

engaging in quantitative description and locational analysis.

After becoming Rushton's doctoral student in 1966 (he then left for Michigan State in 1967), our continuing relationship was expressed and embedded in a series of external structures and particular acts by both of us, which I more fully discuss in the paper. Coincidentally, we became faculty colleagues at the University of Iowa from 1969 to 1973; we have remained friends ever since.

Emphasizing the Importance of Geographical Information in Making Disease Maps: Implications for GIS and Public Health Surveillance

Chetan Tiwari

Rushton and Lolonis in their paper entitled "Exploratory spatial analysis of birth defect rates in an urban population", show that the ability to locate and manipulate objects in geographic space via GIS should be an explicit part of the disease mapping process. Their paper makes several key contributions: (1) A method for mapping disease rates as continuous spatial distributions rather than constrained by administrative boundaries; (2) the use of simulations to map the statistical significance of rates; (3) the use of overlapping spatial filters as a mechanism to account for spatial autocorrelation; and (4) the potential utility of disease mapping as decision support aids for public health surveillance. They suggest novel approaches for the integration of GIS and public health surveillance. These include the development of systems for decision-makers to 'walk the street' using virtual GIS-based software: and knowledge-based spatial analysis systems that would make tentative conclusions about disease clusters.

My research builds on the ideas first proposed by Rushton and Lolonis. In collaboration with Rushton and graduate student colleagues from the University of Iowa, we have developed adaptive spatial filters that dynamically adjust in size to account for differences in population density. Further efforts to improve the

geographic resolution of the map include methods for optimizing the placement of spatial filters across geographic space. Other methodological improvements include the ability to adjust for population differences in age and gender within each spatial filter. Methods for tracking and maintaining consistent filter sizes over multiple data files will permit temporal comparisons of disease patterns. The common thread among all these improvements builds on one key conclusion of their paper: "There needs to be a better balance in research between efforts that involve improving geographic information, and those that involve improving methods of statistical analysis".

Although we have made initial progress in incorporating these methods into semi-automated public health surveillance systems, there is much work that is still needed to realize the development of knowledge-based systems and interactive virtual GIS environments.

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