

This Week's Citation Classic

Wilson A G. A statistical theory of spatial distribution models. *Transp. Res.* 1:253-69, 1967.
[Economic Planning Group, Ministry of Transport, London, England]

This paper offered a theoretical basis for some spatial distribution models which were in common use in locational analysis, and it used a new methodology to generate new models. [The *SCI*® and the *SSCI*® indicate that this paper has been cited in more than 190 publications, making it the most-cited article published in this journal.]

Interaction Patterns in Cities and Regions

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In 1964, I moved from a post in theoretical physics to the Institute of Economics and Statistics at Oxford, looking for the opportunity to be an applied mathematician in a "social" field. My colleagues were economists who had been persuaded that it would do no harm to add a mathematician to a particular research team—one sponsored by the Ministry of Transport. The team's main brief was the cost-benefit analysis of major transport projects. The economic analysis demanded a capacity to predict the effects of any infrastructure changes on travel patterns. I was given the job of investigating the mathematical models that had been developed for this purpose, mainly in the US, in the previous few years.

The available models were known as "gravity models"¹ and were based on a Newtonian analogy that the traffic between two points was proportional to the "mass" (population or jobs, say, for the journey to work) at each end and inversely proportional to some function of the distance between them. The problem was that, unlike the corresponding case in physics, the models did not work very well. A lot of patching up had been done; in particular, a set of correction terms had been introduced known as "balancing factors," though there was no clear rationale for these. But they did make the models "work."

When I was a student, I had taken Part III of the Mathematical Tripos, and I had been particularly interested in statistical mechanics. I assumed then that I was enjoying some very elegant nineteenth-century mathematics that I would never use again. However, when I saw the balancing factors associated with transport gravity models, I recognized that

they looked like partition functions in classical statistical mechanics. But I could not recognize the system that produced them. Much exploration followed, and I first derived the appropriate formula, having constructed an elaborate grand canonical ensemble, and wrote it up in a paper that was never published. Eventually, I found a simpler presentation based on a micro-canonical ensemble, and that formed the basis of the 1967 paper on which this *Classic* is based. I realized that there was a fundamental paradigm shift involved: the gravity analogy was seriously misleading in the transport context; the statistical averaging analogy worked.

As with a number of other good ideas, it later emerged that other people had been working on it at the same time, scattered around the world. I was lucky that it was my paper that attracted the widest attention. Perhaps one reason for this was that the results were presented not just as a piece of algebra that generated the right model, but as a methodology that generated a family of models, contributing to a wide range of problems.

There was another trick that made the original research more widely applicable. By relaxing one of the constraints in the formulation, the model could be turned into a location model rather than simply an interaction model. This broadened the scope enormously for solving a wide range of geographical modeling problems. It also was the basis for providing me with a career in academic geography.

The models still work, and are widely used in a great variety of circumstances. They have not been free from controversy. Their derivation does not fit comfortably with the accepted paradigms "explaining" human behavior in economics or geography. Many have felt uncomfortable with the models because of that. Indeed, much effort has gone into converting them into the formalisms of alternative paradigms. But the alternative formulations do not provide the key insight on why they work.

The models are now applicable in transport planning, retail analysis, health services planning, migration studies, regional economic modeling—any field of geography and economics where spatial interaction lies at the heart of what is happening.²

1. Carrothers G A P. An historical review of the gravity and potential concepts of human interaction. *J. Amer. Inst. Plann.* 22:94-102, 1956. (Cited 105 times.)

2. Fotheringham A S & O'Kelly M E. *Spatial interaction models: formulations and applications*. Dordrecht, The Netherlands: Kluwer, 1989.

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