In Memoriam: C. Bartlett McGuire (1925–2006) and Christopher B. Winsten (1923–2005)

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Fifty years after the publication of the classic book *Studies in the Economics of Transportation* by Beckmann, McGuire, and Winsten (1956), we are mourning the deaths of two of its authors, C. Bartlett "Bart" McGuire, on January 23, 2006, in Richmond, California, and Christopher "Chris" Blake Winsten, May 28, 2005, in Chelmsford, England. That their seminal contributions to transportation science have continued to stimulate our field for over half a century, and now influence fields not even in existence at that time, speaks to the achievement of this incredible book as well as its scientific collaborators. The sad news of both deaths came to us via e-mail, a mode of scientific communication possibly unimaginable 50 years ago; yet their contributions remain fresh and pertinent. Bart McGuire and Martin Beckmann, together with their wives, were present on November 15, 2005, at special sessions organized by us at the INFORMS Annual Meeting in San Francisco, California, where many of us had the privilege of meeting Bart McGuire for the first time.

This story really begins at the Cowles Commission for Research in Economics in 1951, which was then based at the University of Chicago. Under the directorship of Tjalling C. Koopmans, who later received the Nobel Memorial Prize in Economic Sciences in 1975, Martin Beckmann, Bartlett McGuire, and Christopher Winsten began the research that resulted in Part I of *Studies in the Economics of Transportation* (hereafter referred to as BMW). They succeeded in formulating and extensively analyzing a nonlinear optimization problem whose optimality conditions correspond to the statement, "Demand refers to trips and capacity refers to flows on roads. The connecting link is found in the distribution of trips over the network according to the principle that traffic follows shortest routes in terms of average cost. The idea of equilibrium in a network can then be described as follows: ...the existing traffic conditions are such to call forth the demand that will sustain the flows that create these conditions" (Beckmann, McGuire, and Winsten 1956, p. 59). This was an enormous advance in the rigorous modeling of road network traffic, a completely novel result for urban traffic, and most likely for any complex system involving interactions of human behavior with technology. Moreover, they provided a parallel model and analysis for the case of cost-minimizing (now called *system optimum*) flows in a congested traffic network.

Prior to joining the Cowles Commission, Bart McGuire received his BA in economics and political science from the University of Minnesota in 1949, and his MA in economics from the University of Chicago in 1952. Chris Winsten was educated at the University of Cambridge in England. Winsten, a mathematician and economist, had an interest in applying probability concepts to industrial issues, whereas McGuire, an economist, provided a pragmatic and realistic check on the model development and saw the model's description through to publication.

The Cowles Commission Report for the period July 1, 1952–June 30, 1954, noted how Beckmann, Koopmans, McGuire, Winsten, and (during parts of the period) Nerlove and Goldman, formed the team working on two facets of resource allocation problems concerning transportation systems: highway traffic and railway operations. The report noted how highway transportation has many features in common with markets and also emphasized how, in the context of the railroad contributions, "Thus we enter an area of research, variously called 'management science,' 'operations research,' or 'industrial engineering.' "

BMW was the first to provide a rigorous mathematical formulation of the conditions described by the first criterion of Wardrop (1952, pp. 344–348) (also stated in concurrent research) that allowed for the ultimate solution of the traffic network equilibrium

problem in the context of certain increasing link cost functions of flows on the links. In particular, in their book, Beckmann, McGuire, and Winsten demonstrated that the optimality conditions in the form of Kuhn-Tucker conditions of an appropriately constructed optimization problem coincided with Wardrop's first principle. Hence, no traveler acting unilaterally has an incentive to alter his route (assuming rational cost (time)-minimizing behavior) because his travel cost (time) is minimal. Their monograph was published in 1956 by Yale University Press, having been issued earlier as RAND Corporation Report, RM-1488, on May 12, 1955.

Koopmans's report emphasized that the comparison of highway and railroad transportation demonstrated how differences in technology between two different systems serving quite similar purposes can lead to entirely different forms of organization. Hence, their collaboration also planted seeds for the subfield in economics known as "industrial organization." In 1972, McGuire edited a volume with Roy Radner, *Decision and Organization: A Volume in Honor of Jacob Marschak*, who (together with Radner) had been a research associate at Cowles while BMW were there.

BMW also proposed "efficiency tolls," such that by "charging everyone a toll equal to his contribution to the total cost of others, road users can be induced to make an efficient use of the available capacity," and considered how tolls could be constructed in the case of a simple network (cf. p. 94). Congestion pricing through tolls continues today as an area of active research as do many of the topics/problems proposed and studied in BMW, including dynamic transportation networks, algorithms, and stability and sensitivity analysis of network flows.

After leaving Cowles in 1954, Bart McGuire worked at the RAND Corporation until 1961 and then assumed academic positions at the University of California, Berkeley, first at the School of Business Administration and then in the Graduate School of Public Policy (until 1992). During 1993–1994 he served as the Acting Director of the University of California Energy Institute. While at the Energy Institute, McGuire published several reports on decentralization in electric power grids, a topic that fascinated him, along with its (potential) connections to transportation networks. McGuire also published in *Management Science*, *Water Resources Research*, and *Energy and Buildings*.

Chris Winsten was also known for his work in statistics. With S. J. Prais, and while at Cowles, he studied the estimation of trends in the case where "deviations from trends" in a time series are serially correlated. This result became known as Prais-Winsten (1954) regression, a result which is still used by economists today. Winsten had also worked at the Universities of Oxford and London (Imperial College) and in 1968 arrived at the University of Essex to join his former Imperial College colleague, Professor G. A. Barnard, in the Department of Mathematics. At Essex, his specialty was stochastic processes; he served as Dean of Mathematical Studies during 1979–1982. He published in the *European Journal of Operational Research*, *Operations Research*, *Journal of the Royal Statistical Society*, *Series A* and *Series B*, *Econometrica*, and *Journal of Transport Economics and Policy*.

Fifty years after its publication, BMW is finding applications in disciplines that did not even exist when the book was published, such as computer science in the case of decentralized decision making and the Internet, games on networks, and bounding the price of anarchy! We expect that there will be continuing cross-fertilization between many fields in which networks play a prominent role, with BMW serving as one of the fundamental references. Indeed, BMW laid the intellectual and economic scientific foundation for transportation systems analysis, planning, and evaluation for the rest of the twentieth century and beyond. Moreover, as the above discussion reveals, the work provided linkages to other application areas and fields. As noted in Boyce, Mahmassani, and Nagurney (2005), the ideas and concepts are fundamental and are unlikely to change in the foreseeable future. In conclusion, we raise again the question posed by Boyce, Mahmassani, and Nagurney (2005, p. 98): Have we left the next generation a contribution that is as far-reaching and thoughtful as what Beckmann, McGuire, and Winsten have given us?

Through Boyce's efforts, RAND Report RM-1488-PR (BMW 1955) is now available free of charge as a RAND Classic on the RAND Corporation website. For the link to the report, and the PPT presentations at the special INFORMS sessions in San Francisco (November 2005) as well as a special session at the Regional Science Association International's North American Meetings in Philadelphia (November 2003), see: http://supernet.som.umass.edu/classics.htm.

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