

In Memoriam: Martin Beckmann (1924-2017)

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Over sixty years since the publication of the classic book *Studies in the Economics of Transportation* by Beckmann, McGuire, and Winsten (1956), we now mourn the death of Martin Beckmann on April 11, 2017 in Providence, Rhode Island. That his seminal contributions to transportation science and location theory have continued to stimulate our field for well over half a century speaks to the achievement of this book as well as his other books and scientific papers.

The first version of *Studies* was a 1954 report to the Rand Corporation, which had sponsored the research. That report was much later declared to be a Rand Classic, and can be downloaded at no charge (https://www.rand.org/pubs/research_memoranda/RM1488.html). Beckmann (1967) did write a short paper for *Traffic Quarterly*, the only transportation journal then published in the United States. Over ten years later, however, transportation network equilibrium was the subject of four doctoral dissertations, 1968-1974: Stella Dafermos, Suzanne Evans, Larry LeBlanc and Sang Nguyen. At an international symposium in 1974 organized by Michael Florian (1976), the research initiated at the Cowles Commission became better recognized.

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 received the Nobel Memorial Prize in Economic Sciences in 1975, Martin Beckmann, Bartlett McGuire, and Christopher Winsten initiated research that led to Part I of *Studies in the Economics of Transportation*; see also Boyce and Nagurney (2006). 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 congested 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; Cowles, 1952-1954, pp. 12, 13 and 26). This was an enormous advance in the modeling of road network traffic, completely novel for urban traffic, and likely for any complex system involving interactions of human behavior with technology.

Beckmann, McGuire and Winsten were the first to provide a rigorous mathematical formulation of the conditions described by the first criterion of Wardrop (1952, pp. 344–348) (as was also stated in their 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.

They demonstrated that the optimality conditions in the form of Kuhn-Tucker conditions of an appropriately constructed optimization problem coincided with Wardrop's first criterion. 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. (In an interview with Boyce in 1999, McGuire stated that this formulation was provided by Beckmann.)

They 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 (now also called *system optimum model*) continues today as an area of active research. A thorough analysis of the contribution of Part I of their book was given by Boyce, Mahmassani and Nagurney (2005).

Martin Beckmann also pursued related research topics while at the University of Chicago during 1950-1954, as analyzed by Boyce (2014). Beckmann formulated the continuous model of transportation, which has now been made operational by scholars in Hong Kong, and studied assignment problems and the location of economic activities with T. C. Koopmans. Extensive references to these works were given by Boyce.

Martin Beckmann was born on July 5, 1924 in Ratingen in the county of Düsseldorf, Germany. His youth was marred by war, when he was drafted into the German army. After 1945, Martin studied mathematics and economics at the University of Goettigen, 1945-47, receiving a B.A. in mathematics, and then studied economics at the University of Freiburg, 1947-50. He completed his *Doctor rerum politicarum, summa cum laude*, in 1950. He did postdoctoral research at the University of Chicago, and then took an assistant professorship at Yale University, 1955-1959. He then held simultaneous professorships in economics at Brown University, 1959-1989, and at the University of Bonn, Germany, 1962-1969, and then in applied mathematics at the Technical University, Munich, 1969-1989. He authored or co-authored 14 books, edited 10 books and authored over 220 articles by 1992.

Martin became an acclaimed and beloved scholar, who won numerous awards and honorary degrees for his groundbreaking research. He was awarded the first Robert Herman Lifetime Achievement Award in Transportation Science by the Transportation Science Section of the Operations Research Society of America (now INFORMS) in 1994. He received the first Founder's Medal of the Regional Science Association in 1983, following its creation in honor of Walter Isard in 1978. He received honorary doctorates from the University of Karlsruhe, 1981, the University of Umea, 1981, and the Bundeswehr Hochschule Hamburg, 1984.

In 2005 two special sessions of INFORMS were held at its annual meeting to honor the co-authors of *Studies*. Martin, and Bart McGuire, were able to attend; Chris Winsten had died one year earlier. David Boyce and Anna Nagurney organized these sessions. A highlight was the presentation of a citation by Philip Haile, Director of the Cowles Foundation for Research in Economics, on the 50th anniversary of the publication of *Studies*.

Martin had served on Anna's Ph.D. dissertation committee at Brown University in 1983. His final question was, "When do we get to eat the nice food that Anna brought for us!" Anna has

published many papers and books related to Martin's research. David had met Martin in 1968 at the Budapest Congress of the Regional Science Association. Although he was aware of Martin's contributions, he did not understand thoroughly the meaning of *Studies* until 1983. In 2013 he wrote a short article explaining the optimization result (Boyce, 2013), as well as extending his results in papers and a book.

As Boyce (1994) stated in the citation for the Herman Award, "I think of the encouragement Martin provided to each of us by listening carefully and commenting on our papers; by offering his support and friendship to younger colleagues; by showing us how to enjoy excellent food, fine music and art, and the companionship of others, while always maintaining his excitement, enthusiasm and love for our science."

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