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STEVEN VAJDA

JAKOB KRARUP

Known as the British father of linear programming (LP), Steven Vajda was a mathematician, educator, mentor, one of mathematical programming's true pioneers, and the person who introduced linear programming to both Europe and Asia. He was a fellow of the Royal Statistical Society, was awarded an honorary doctorate degree from Brunel University (West London), and was promoted Honorary Doctor of Philosophy by the University of Budapest.

Steven's 1956 book, *Theory of Games and Linear Programming*, was the first book to present a systematic and comprehensive account of matrix games and LP. Translated into German, French, Japanese, and Russian, it was also the first book on LP published outside the U.S. and the second one worldwide. To many in Europe and Asia, this text was their first introduction to a promising new area and a revelation that matrix games and LP were so intimately interrelated. It is, therefore, Steven who rightly should be credited for having spread the message to the two continents. For over 50 years, Steven was a key figure in the development, in the U.K., of post-war operations research (OR), in general, with particular emphasis on mathematical programming (MP).

EARLY CHILDHOOD AND FAMILY

Steven (István, originally) was born in Budapest on August 20, 1901 to Josef and Aurelia (Wollak). Little is known about his parents, but both are believed to have been born in Vienna. Josef left school as soon as he could and was employed as a traveling salesman, selling handkerchiefs. Aurelia was never employed.

The family moved to Vienna in 1902 when Steven was 16 months old. Steven attended the local primary school and won a place at the Akademisches Gymnasium, a selective school for intelligent students. He excelled in mathematics, languages (he spoke eight languages as an adult), and European history. He was also a keen boy scout and loved football (soccer).



There were two siblings, an older sister who died in infancy, possibly from scarlet fever, and a younger sister Ilonka who married a Czechoslovakian and moved to Prague before World War II (WWII). After the war, Steven tried to find out what had become of his family and was told that his father died of pneumonia in a concentration camp, and his mother perished in a gas chamber. There was no information available about Ilonka.

Between the two world wars, Vienna was a focal point of intellectual activity. Steven took a great interest in the modern philosophies of the day such as psychoanalysis and met with many of the most original thinkers of the twentieth century: philosophers, notably Karl Popper; members of the Vienna Circle (the circle of scientifically minded intellectuals); the physicist Dennis Gabor, the inventor of the hologram; and the mathematician/logician Kurt Gödel whose Incompleteness Theorems managed to generate a turmoil within the community of mathematicians.

As an adult, Steven engaged in printing and book-binding as hobbies, and, throughout his life, maintained a great interest in European history. He was an interesting and stimulating traveling companion who not only planned trips to see as much as possible, but also was able to give detailed accounts of places, people, events, and dates.

In 1929, Steven married Eva Paulina Fanta, a bank manager's daughter. She was born in Vienna (1906) and was trained as a teacher. They had two children, Hedy (1930) and Robert (1933). Eva died in 1983.

ACADEMIC TRAINING, MENTORS, AND INFLUENCES

Steven originally embarked on an engineering degree at the Vienna Technical University but changed to a 2-year course in actuarial science. On completing the course, he found it difficult to find employment and transferred to the University of Vienna to take a 3-year course in mathematics. Upon further studies, he received the Ph.D. degree in 1925 and subsequently attended the University of Göttingen for one semester.

At that time, Göttingen ranked as the stronghold of mathematics. Here, Steven met a range of eminent mathematicians: David Hilbert, Richard Courant, Emmy Noether, and Bartel van der Waerden who guided Steven to an actuarial job in Romania. Steven took this job as he was unable to obtain employment in Vienna; he was not a member of the local Social Democratic Party.

He stayed in Braila (Romania) for just 18 months (1926–1927) and then returned to Vienna where he was invited to join the actuarial staff of the Phönix Insurance Company. This job offer came about due to some work he did while in Romania. Steven had carried out an evaluation (the exact insurance situation is unclear) and, because he had no idea how he was expected to carry out the assignment, he designed his own unique method. From this study and related activities, he became rather well known in the local actuarial community. In 1936, he transferred to another insurance company which assigned him to Budapest for 6 months, but, otherwise, Vienna was his home base.

“HITLER DIDN'T LIKE ME VERY MUCH...”

Hitler's steady demand for Lebensraum led to the annexation of Austria (the Anschluss) in 1938. With the Nazis occupying the country, the Vajda family felt compelled to leave. Their children, Hedy and Robert, were dispatched to Sweden. Later, Eva left Vienna for Sweden to pick up her children and then to England where she supported herself in domestic service.

It was difficult for Steven, however, to obtain a visa for England. He contacted his old friend Karl Popper, who was teaching at the University of Christchurch in New Zealand, about employment there. He was offered a job, which also enabled him to obtain a temporary visa to travel via England to collect his wife and children. Three months after his arrival in England, WWII broke out, Britain declared war on Germany, and the family could not continue to New Zealand.

It is no wonder that there was some panic in the U.K. about potential spies among travelers arriving from Central Europe. As an enemy alien, Steven was interned on the Isle of Man, but his family was allowed to remain in Epsom. They were lucky aliens in that many others, who were being sent to Canada, had their ship torpedoed. During his stay at the internment camp, along with about 1,600 other refugees, Steven was instrumental in establishing a do-it-yourself university where he taught mathematics to the younger students and helped them prepare for university entrance examinations; an entrance exam he prepared was approved by the University of London.

As Steven once said, “Hitler didn’t like me very much, but then I didn’t like him very much either” (Haley and Williams 1998, 299). As evidenced during the subsequent 55 years, these mutual antipathies were indeed fortunate for British OR and, in turn, for the mathematical programming community worldwide.

CITIZEN OF THE U.K.

After 6 months on the Isle of Man, Steven’s record was reviewed and it was decided that he was not a danger to the country. Supported by friends in Vienna, he then joined the Gresham Insurance Company located near Epsom. Once again he was lucky. The British consul in Vienna had forgotten to stamp his passport with a statement saying that the owner is allowed into England but not to take a job.

In 1944, Steven was approached by the statistician, Hilary Seal, who was setting up a new statistical department at the Admiralty for the purpose of maximizing military resources in the Pacific. On the basis of Steven’s actuarial research publications, which he wrote prior to leaving Austria and which were published in *Bulletin des actuaires suisses*, Seal invited him to join his group at the Admiralty. This was in fact the

beginning of his career in OR. When the war ended, Seal saw to it that Steven was one of the first aliens to be given British citizenship.

Steven worked for the Admiralty until 1965, first as a statistician, soon rising to assistant director of physical research. In 1949, he was appointed assistant director of OR, and, in 1952, he was promoted head of Mathematics Group at the Admiralty Research Laboratory at Teddington. Steven's work

STEVEN THE LEADER

The name Vajda does actually mean something in Hungarian. It appears that the word can be found in Hungarian texts dating back to about AD 950. A Vajda is sort of a regional leader or a reigning prince and close variants are known in ancient Greek, Polish, ancient Russian, Serbo-Croatian, and Slovenian. Vajdaság, the region led by Vajda, is the Hungarian designation of a region in the northern part of former Yugoslavia.

for the navy spanned manpower planning, military OR, and the provision of mathematical, statistical, and computational services.

Patrick Rivett was the first professor of OR in the U.K. (Lancaster University, 1963). Steven became the second one when he joined the University of Birmingham in 1965, a position he held until his retirement in 1968 when he became a senior research fellow. In 1967, he was invited by Sussex University to become a fellow, and, in 1973, became visiting professor of mathematics, a role in which he remained active by teaching and writing research papers for about 22 years—probably a record unsurpassed in the U.K. and anywhere.

CONTRIBUTIONS TO OR AND BEYOND

It is not quite obvious what Cowles Commission Monograph No. 13, *Activity Analysis of Production and Allocation* (Koopmans 1951), may have had to offer Steven. This volume, however, contains a paper titled “Maximization of a linear function subject to linear inequalities” by a certain G. B. Dantzig (1951), along with two other papers by the same author, one of which is a revision and extension of an earlier paper which appeared in the journal *Econometrica* (Dantzig 1949). These were the earliest publications on what has since been named LP. They became Steven's gateway to the field.

Steven became excited about these new ideas, their potential in practice, and the abundance of theoretical challenges, and he was eager to share his enthusiasm (Vajda 1956, 1958). He took a particular interest in

duality, a central concept in LP, a powerful modeling tool, an equally powerful modeling principle, and a means to appreciating what post-optimal analyses may have to offer. Furthermore, as H. P. Williams, one of Steven's closest collaborators notes:

A major achievement of Steven Vajda was to explain the implications of duality in a wide variety of seemingly unrelated contexts, e.g. combinatorics and graph theory, flows in networks, game theory, and economics. . . . Perhaps most surprising is its applications to certain problems in combinatorics, e.g. Menger's theorem and the König-Egerváry theorem since these problems belong to the realm of discrete mathematics and superficially appear to have nothing to do with the continuous mathematics of LP. Of course, when these problems are cast in an LP form, the optimal solutions are integral, which results in the relevance of LP (Williams 1997, 203).

Steven was presumably the first person in Britain who realized these connections and, characteristically, to enthusiastically share them with others. His results in this direction are reflected in his books (Vajda 1961, 1962) that have served as textbooks in many university and industrial courses.

Manpower planning can be defined as the problem of determining the number of personnel and their skills that best meet the future operational requirements of an enterprise. It is basically a management decision problem concerned with "arranging for the right number of individuals to be allocated to various well-defined activities," . . . where "the tools of manpower planning include transfers, promotion, and recruiting" (Vajda 1978, 1). It is not exactly clear as to what first motivated Steven to study this field, but he does note that its origins go back to the 1940s when he was a statistician with the Admiralty (Vajda 1978). His colleague there, Hilary Seal, wrote a paper on the mathematics of a population (Seal 1945), which Steven followed with a related paper (Vajda 1947). Here, Steven's research dealt with mathematical analyses of such problems as "a stratified population, which is subject to (i) mortality, dependent on age, and to (ii) promotion rates, indicating the ratios of members of a grade which are transferred to the next higher grade at the end of the year" and extends to situations which have been "of actual importance in practical establishment work: the promotion rates are made dependent on the time spent in the grade instead of on the age" (Vajda 1947, 253–254). These practicalities of a population are conditions and/or constraints that need to be considered when analyzing manpower planning problems.

Steven later returned to manpower planning research when he was senior research fellow at the University of Sussex. This culminated in his book, *Mathematics of Manpower Planning* (1978). Graham Rand (1979, 767–768), in his review of the book, notes as follows: “[In] Part I, Vajda, starting from the basic concepts of a cohort with a hierarchy of states and rates of transfer between states, deals first with a workforce whose total is kept constant by new entrants and then with a workforce where all the hierarchical state totals are kept constant (a stationary workforce). If only the totals of certain subsets of the states are kept constant, the workforce is semi-stationary (a concept introduced by Steven). . . . In Part II, the questions of what structures can be attained, reattained and partially retained after t steps are investigated. The penultimate chapter, Optimization, is concerned with the determination of the most preferable way of moving from one structure to another.” (Rand notes, “it must be stressed that this is, as the name implies, a book of mathematics.”) Novel to Steven’s later manpower research is the application of optimization techniques, especially the simplex and dual simplex methods of LP (Vajda 1975, 1978).

Possibly the best account of Steven’s professional achievements as an author, educator, and mentor is given by Haley and Williams (1998). They give a complete listing of Steven’s works. Whereas his most significant contributions fall within MP, with particular emphasis on LP, other, less known topics are cited, such as his series of papers (in German) on actuarial science, a topic in which he maintained a long-term interest (Vajda 1984). Steven, in addition to his writings, was an essential contributor to a wide variety of courses on both LP and general OR that were offered in the U.K. from the mid-1950s.

Steven’s research investigations extended to related areas in group theory, geometry, cryptography, and experimental design, often with links to mathematical programming.

Noteworthy are his works on Fibonacci and Lucas numbers, and the Golden Section. An excellent account of the diversity of Steven’s interests within pure and applied mathematics is

MATHEMATICIANS ARE SIMPLE . . .

“Mathematicians are simple folk, easily amused, quiet and amiable. They have no need for extraneous diversions since there are plenty of inner thoughts and puzzles to keep the mind busy. They make good husbands, even if their abstraction is sometimes infuriating. And lest I be thought sexist, I should add that they also make good wives when they are of the feminine gender” (Conolly and Vajda 1995, 15).

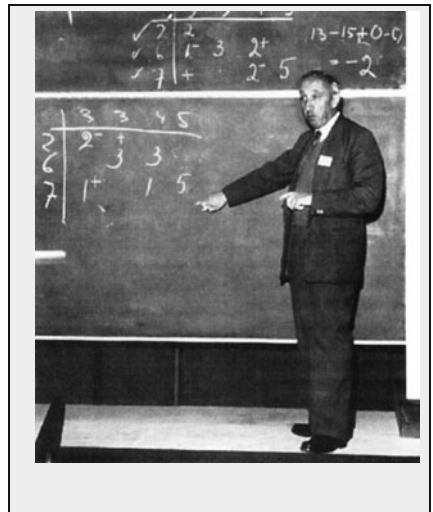
his 15th and last book, *A Mathematical Kaleidoscope*, coauthored with Brian Conolly, and published a few weeks before his death (Conolly and Vajda 1995). This collection of essays is derived from various sources—mathematical moments one might say. Truly delightful reading!

HONORS AND AWARDS

Steven was a member of the Institute of Actuaries and a fellow of the Royal Statistical Society, London. He was awarded an honorary doctorate (Doctor Technices *honoris causa*) at Brunel University in 1971, and an Honorary Doctor of Philosophy at University of Budapest in 1975.

His outstanding contributions to OR were also recognized by the British Operational Research Society (ORS), by granting him honorary membership in 1986, and by publishing a special issue in honor of Steven Vajda's 91st birthday, edited by B. Conolly (1992).

On February 10, 1995, a meeting honoring Steven was organized at the Monopolies and Mergers Commission, London. Once again, duality was in focus. In his talk "Where is duality hiding?" Steven asked for the connections between Dantzig's simplex algorithm and Nobel laureate Kantorovich's approach; a question answered afterward by Susan Powell (1997). At the end of the meeting, Steven was presented with the ORS Companionship of OR by Professor Lyn Thomas, then President of ORS. The citation by Professor M. F. Shutler (1997) together with most of the papers presented can be found in Powell and Williams (1997).



The after-dinner speech was given by Brian Haley who can claim to have been the first academic colleague of Steven. He recalled Steven's propensity to retire, the first being from the Admiralty into academia. This was followed by his further retirements from a number of other

academic posts. In his reply, Steven noted that he was famous for having retired four times and that the best thing that he could do then was to retire again so that people could get on by enjoying themselves. He did, and they did.

Martin Beale was among those recruited by Steven into the Admiralty. When EURO (Association of European Operational Research Societies), in 1988, honored Martin posthumously with the EURO Gold Medal, it was Steven who gave the speech of thanks, with a full paper containing many new ideas and reflecting his concerns.

MENTOR AND FRIEND

My life as an OR worker embarks from the early years (1958–1964) during which I was affiliated with Regnecentralen, The Danish Institute of Computing Machinery, where, literally, Danish datalogy was born. The climate around the first digital computer in Denmark and its users was appealing in every conceivable respect. Even an OR division materialized. From conceptually simple scenario analyses, we moved on via LP and were soon spellbound by the magic of the computationally intractable integer problems.

The prime influence of Steven's second textbook, *Mathematical Programming* (1961), purchased for Regnecentralen's library, cannot be overrated in this context. It was instrumental when the above-mentioned OR division was created, and, sans comparaison, our key reference during these first years of development. Not only did it introduce the various families of optimization problems and the algorithmic tools employed for their solution, but it also introduced the scope and limitations of MP as a means for investigating managerial and other decision problems via prescriptive models.

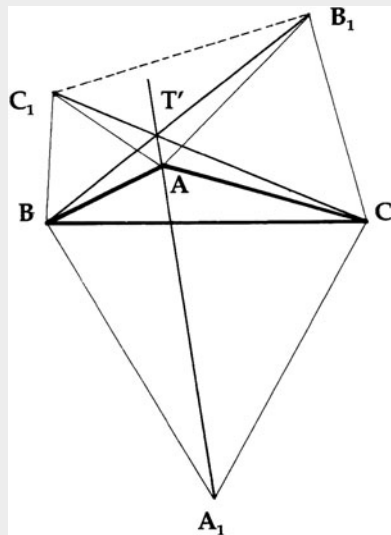
These directions were further pursued in my Ph.D. work. The most important event of that period was a 1966 NATO Summer School held in Italy. An invited speaker was awaited with particular anticipation, a Professor S. Vajda who, in a very suggestive way, highlighted the significance of duality as a central concept within MP and whose visions and thought-provoking viewpoints, in general, left a strong impression on all those present.

We met again in 1992 at a conference in Hungary where Steven delivered the opening lecture. Afterward, we discussed the earliest occurrence of duality in general nonlinear programming. I was able to recollect most of Harold Kuhn's findings as presented at the Mathematical Programming Symposium (Budapest, 1976) and, to my great surprise, thus to tell Steven just a little bit about duality which was new to him.

The story about the primal problem, a challenge thrown out in 1643 by Fermat, and its dual, a brainteaser published in 1755 in *The Ladies Diary or Woman's Almanack*, has, since Kuhn's presentation, been ranked as the first instance of duality (Kuhn 1976, 7). Whether some credit actually should go to St. Matthew is still an open question (see Matthew 11.11). Steven enjoyed the story. We both knew that Torricelli came up with a geometrical solution; neither of us, however, was familiar with the details so

FERMAT, VAJDA, ET AL.

A famous problem due to Pierre de Fermat is to find a point T inside a triangle (ABC) such that the sum of the straight-line distances from T to the vertices A , B , and C is minimal. An application is when A , B , and C are warehouses and T is a factory supplying goods to the three warehouses. The mathematicians Evangelista Torricelli, Thomas Simpson, and others developed geometric-based solutions, but they hold only if all of the angles of the triangle are less than or equal to 120° . If an angle is equal to 120° , then T is at the vertex of that angle. In their book, *What Is Mathematics*, Courant and Robbins (1941) addressed the situation when an angle is greater than 120° . There they stated that if you apply Simpson's method, the associated point, here T' , is such that the sum of the distances ($BT' + CT' - AT'$) is minimal. They left the proof of what they termed the "complementary problem . . . as an exercise to the reader" (Courant and Robbins 1941, 358). With Steven a reader, along with this author, and the result as stated being incorrect, one would expect the situation to be appropriately remedied. This is reflected by Steven's last paper (Krarup and Vajda 1997), which later led to Jalal and Krarup (2003) and Krarup (1998).



it was decided to investigate the matter further. The result appeared in Krarup and Vajda (1997).

Another incentive for further joint studies was an error made in the famous book *What Is Mathematics?* (Courant and Robbins 1941). Also, a paper on “Visualizing duality” was on the drawing board at the time Steven passed away. It meant to exhibit a series of examples within linear, nonlinear, and combinatorial programming where the notion of duality appears to be particularly conspicuous.

Even more valuable, however, was the friendship that evolved between us through these endeavors. Similar debts to Steven are in one way or another owed by many others. Since Steven joined the Admiralty, he spent about 50 years consciously or unconsciously motivating the careers of numerous OR workers. He has exerted this influence directly by teaching and conference presentations and indirectly by his writings and by the example of his life.

With an amazing mobility, Steven remained a frequent traveler to conferences and symposia. Insight and an implacable curiosity marked his active contributions as a lecturer or discussant. Likewise, no effort was spared outside the conference halls. Not even the extremely hot weather in Israel in July 1995 discouraged Steven from taking part in the physically demanding 2-days’ excursion to Galilee organized in conjunction with EURO XIV conference. Not a single detail was missed, let alone the celebrations of EURO’s 20th Anniversary. The organizers of the conference were honored to have him as the oldest participant ever at a EURO event. The International Federation of Operational Research Societies Vancouver conference in 1996, with a pre-conference hike in the Rockies, was supposed to be “next time” (Krarup 1996, 12).

It is a gift of grace to shuffle off this mortal coil after having enjoyed a long life without suffering the physical horrors of old age and even more so to preserve both a warm heart and a brilliant mind to the end. Those gifts were granted to Steven Vajda, still teaching and writing in his 94th year before he passed away after a short illness on December 10, 1995. As the panegyric at his funeral noted, he had the capacity to make everyone he met believe that they were his friend. Therein lays the truth of his memory (Krarup 1966, 437–439).

ACKNOWLEDGMENTS

The primary sources for this profile are the interview (Bather 1995), the detailed account of Stevens's work (Haley and Williams 1998), M. F. Shutler's citation for the Award of the Companionship of the Operational Research Society to Steven (Shutler 1995), and the obituary by Krarup (1996). Supplementary material, not available elsewhere, was acquired via personal communication with Steven's daughter, Hedy Firth, and his last coauthor, Brian Conolly. Their kind assistance and permission to use, quote, and paraphrase their material on Steven is gratefully acknowledged.

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