

THE LIFE AND SCIENTIFIC DISCOVERIES OF GEORGE BERNARD DANTZIG “FATHER OF LINEAR PROGRAMMING AND FOUNDER OF OPERATIONAL RESEARCH”

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Abstract

The purpose of the present paper is to describe the life and scientific discoveries of George Bernard Dantzig (1914-2005), as well as the environment in which he lived and worked. We describe, also the main discovery of Dantzig in the newly established scientific discipline of Operations Research, namely, the Simplex Method for solving Linear Programming problems. We mention in this paper the two scientists, namely: Tjalling C. Koopmans and Leonid V. Kantorovich, who have discovered similar methods for solving Linear Programming problems and they have been awarded jointly the Nobel Prize for their contributions to the Theory of Optimum Distribution of Resources. Finally, some comments on the life and work of Professor. Dantzig are made.

Περίληψη

Ο George Bernard Dantzig (1914 – 2005) υπήρξε πρωτοπόρος των καινοτόμων μαθηματικών μεθόδων (θεωρητικών και εφαρμοσμένων), που ήταν βασικές στην ανάπτυξη και την αποτελεσματικότητα του τομέα της Επιχειρησιακής Έρευνας. Σπούδασε Μαθηματικά στο University of Maryland, έκανε μεταπτυχιακό στο University of Michigan και το 1946 έλαβε το Διδακτορικό του στα Μαθηματικά από το University of California.

Το 1947 επινοεί τη Μέθοδο Simplex, την πλέον γνωστή και περισσότερο χρησιμοποιούμενη μέθοδο για την επίλυση ενός γενικού προβλήματος Γραμμικού Προγραμματισμού. Η μέθοδος αυτή αποτελεί μια αλγεβρική επαναληπτική διαδικασία, η οποία επιλύει ακριβώς κάθε πρόβλημα Γραμμικού Προγραμματισμού σε ένα πεπερασμένο πλήθος βημάτων. Έκτοτε έχει εφαρμοσθεί παγκοσμίως σε πληθώρα βιομηχανιών, εμπορικών επιχειρήσεων και κυβερνητικών οργάνων επιτρέποντάς τους να επιτύχουν την αποτελεσματικότερη διαχείριση των πόρων τους. Η συνεισφορά του G.B. Dantzig ήταν πολύ σημαντική στα Μαθηματικά, την Οικονομική Επιστήμη, την Στατιστική, την Βιομηχανική Εφαρμοσμένη Μηχανική και την Πληροφορική.

Κατά τη διάρκεια της ακαδημαϊκής του καριέρας διετέλεσε Καθηγητής της Μηχανικής Επιστήμης και Πρόεδρος του Ερευνητικού Κέντρου Επιχειρησιακής Έρευνας στο University of California (1960 – 1966). Επίσης υπήρξε Καθηγητής της Επιχειρησιακής Έρευνας και της Επιστήμης των Υπολογιστών στο Stanford University (1966 – 1973). Τέλος ήταν ιδρυτικό μέλος και διετέλεσε Πρόεδρος του Institute of Management Science και έλαβε πλήθος τιμών και διακρίσεων.

Keywords: Simplex Method., Linear Programming, INFORMS (Institute for Operations Research and the Management Sciences), Operational Research, Nobel Prize.

His life

*“Life is good for only two things, discovering mathematics and teaching mathematics”
Simeon Poisson (1781 – 1840)*

George Bernard Dantzig (1914 - 2005) (Figure 1) was a pioneer of the innovative theoretic and applied mathematic methods, which were primarily focused on the development and effectiveness of Operational Research. During the last 62 years, his creative work in Linear Programming and its extensions have been applied worldwide in a massive number of industries, including commercial businesses and governmental organizations. Its application allowed them to achieve a more effective management of their resources. As a result, the development of Linear Programming and the invention of the algorithm Simplex are recognized as important scientific contributions of the 20th century.

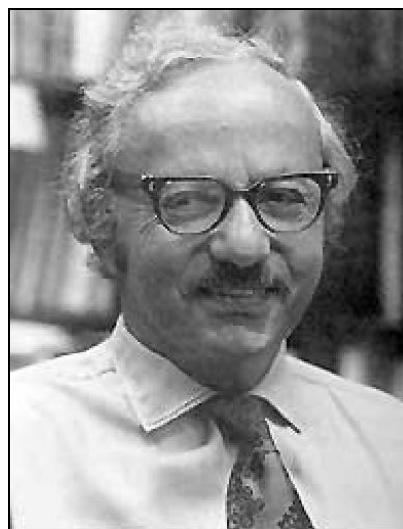


Figure 1. George Dantzig

Furthermore, Dr Dantzig made a significant contribution in Mathematics, Economics, Statistics, Industrial Applied Mechanics and Information Technology. More in particular, he was chairman of the Institute of Management Sciences, which was predecessor and co-establisher of the Institute for Operations Research and the Management Sciences (INFORMS).

G.B. Dantzig's parents were Tobias Dantzig and Anja Ourisson. Tobias Dantzig was born in Russia, but moved to France, where he studied Mathematics in Paris, having ¹*Jules Henri Poincare* as a tutor, among others. During that time he meets Anja Ourisson who was studying Mathematics in Sorbonne. They got married and in 1910 they moved to Portland, Oregon in USA. Tobias thought that his heavy Russian accent would not allow him to find another job, besides that of a workman. Thus, he worked in road construction, as a lumberjack and as painter. At that time, on November 8, 1914, George was born, the first of two sons in the family. It has to be mentioned that this happened when the Dantzig family were experiencing financial problems.

Despite this fact, Tobias managed to get a teaching position in the Indiana University, where he got his Doctorate in Mathematics in 1916. He then taught in the John Hopkins University and in the University of Maryland, where he was also chairman of the Department of Mathematics. He had a unique ability in conceiving and explaining Classic Mathematics. His book ²*“Number: The Language of Science”* published in 1930 was praised by Albert Einstein: “This is beyond doubt the most interesting book on the evolution of mathematics, which has ever fallen into my hands”.

When Tobias got his two sons, he believed that the choice of names he would give them would determine to a great extent, their future course and career. For his first son, he chose the name George Bernard and later ³*George Bernard Shaw*, naming him after the famous Irish writer, hoping he would one day become a writer, too. The second son was named Henri and later Henri Poincare, after the already famous Mathematician Henri Poincare, with the hope that he would be a Mathematician. Henri, indeed, became a Mathematician and Mechanic and worked as a radar mechanic. Henri Poincare Dantzig died in 1972.

Meanwhile, Anja took her Postgraduate Diploma and then worked as a linguist in the Library of Congress in Washington DC.

George Bernard's family lived in Washington DC. He went to the Powell Junior High School. At first, his interest in Mathematics was minor as well as his records. His father was always helping and encouraging him, and as a result Mathematics became George's favorite class and the course where he achieved the highest marks. This continued at Central High School, where he was fascinated by Geometry. At that time, he was getting support from three people, an exceptional Mathematician at school, a co-student of his, later teaching Mathematics in Berkeley and of course his father. Tobias produced thousands Geometry problems, while George Bernard was still in High School and he later confessed that the mental exercise required to

¹ Jules Henri Poincaré (1854 - 1912). French Mathematician with great contribution to many fields of pure and applied mathematics, like celestial mechanics, fluid mechanics, optics, electricity, telegraphy, trichoid phenomena, elasticity, thermodynamic, dynamic theory, quantum theory and cosmology. He is believed to have contributed to the discovering (along with Albert Einstein and Hendrik Lorentz) of the Special Theory of Relativity.

² One of the most important books about Mathematics refers to the evolution of Mathematics and explains the concept of numbers in history. It reports on many issues, such as the function of numbers, the invention of zero and infinity. It also indicates how the evolution of numbers is connected with the history of human civilization.

³ George Bernard Shaw (1856-1950) Irish playwright, honored with a Literature Nobel Prize in 1925.

solve them, was the greatest gift his father ever gave him. These problems played the most important role in the development of his analytical thought. Moreover, while Tobias was working on his famous work "Number: The Language of Science", George Bernard assisted him by preparing some of the numbers that appear in the book.

After his graduation from Central High School, G.B. Dantzig decided to study Mathematics in the University of Maryland, where his father was teaching, too. Despite the improved financial situation of the family, Tobias could not afford the study fees of his children in some acclaimed University of the States. G.B. Dantzig took his degree in Mathematics and Physics from the University of Maryland in 1936, at the age of 22. The summer of the same year, he got married to ⁴*Anne Shmuner*, who had met at university. The couple moved directly to Ann Arbor, where G.B. Dantzig began his postgraduate studies at the University of Michigan. In 1937, with T.H. Hildebrand, R.L. Wilder and the G.Y. Rainer as instructors, he completed his postgraduate diploma in Mathematics. Due to the fact that during his studies he wasn't particularly pleased with abstract Mathematics and the only course he actually enjoyed was Statistics, he decided not to proceed to a Doctorate degree. Instead, he moved to Washington DC, where he worked from 1937 to 1939, as an assistant statistician, in a program for the US Bureau of Labor Statistics, called "Urban Study of Consumer Purchase". Right after the end of this program, he addresses to ⁵*Jerzy Neyman* and asks for a Doctorate under his supervision, in Berkeley. J. Neyman agrees and G.B. Dantzig begins his studies, while at the same time he works as a teaching assistant of J. Neyman.

During his studies in Berkeley, an incident that would later change his life, took place. One day, he arrived late in class and saw two problems written on the blackboard. Assuming they were for homework, he simply copied them. A few days later, he apologized to Jerzy Neyman for taking him so long to finish his homework, but it seemed to him that the problems were a bit more difficult than usual. He asked him if he could still hand him in his papers, despite being late. J. Neyman told him to leave them on his desk, where there was already a huge pile of other papers. G.B. Dantzig hesitated at first, worrying his work getting lost among the rest of the papers, but couldn't do anything about it. Six weeks later, on a Sunday morning at around 8 o'clock, George and Anne got an unexpected visit at their home by J. Neyman, who was holding some papers and asked G.B. Dantzig to take a look at them, before sending them out for publication. Dantzig, still confused, couldn't realize what was really happening. After the necessary clarifications, it became clear to him that the problems he delayed' handing over were in fact two acclaimed ⁶*unsolved problems in statistics*.

During World War II, G.B. Dantzig gave up his studies once more, even though at that point he had already completed the coursework and his Ph.D. thesis. He went to Washington DC and joined the Martial Aviation, as a civilian. From 1941 to 1946 he was in charge of the Combat Analysis Branch of Statistical Control, U.S. Army Force, Pentagon and Washington DC. In 1944, he was granted with the War Department Exceptional Civilian Service Medal. In his office he collected elements regarding sorties flown, bomb casting, air combats, factors of deterioration and loss of aircrafts. He was also an assistant in other departments of Air Staff, preparing certain plans called 'programs'. Every single thing, from supplying aircrafts with spares to any other project concerning aircrafts, was planned with great detail, even though he had to deal with different kinds of material and around fifty thousand specialized technicians. In that way, he also improved his expertise regarding organization and technical work.

In 1946, after a five-year break, G.B. Dantzig returned to Berkeley for a semester, where he got his Doctorate in Mathematics from the University of California. He was also offered an Academic position in that University, but he rejected it for being economically disadvantageous. They offered him precisely 1,400 dollars annually, but he didn't accept the offer, thinking that since his family had a new member, his son David, their expenses would increase and therefore would not be covered by that amount.

Until June of 1946, he remained in Washington DC examining various possible work positions. After a while, he was offered a position in the Pentagon, as an Advisor in the USA Ministry of Defense, which he accepted. His goal was to calculate how the Martial Aviation could mechanize its planning process, in order to accelerate the deployment of forces and equipment, as well as compute a time-staged deployment, training and logistical supply program. It was a project that suited precisely to his capabilities and interests.

⁴ Anne Schmurmer Dantzig (1917-2006). She was born in Maryland. Her parents were immigrants from East Europe. She studied French at the University of Maryland, and Librarianship at the University of Michigan. She worked in the Library of Congress and dedicated a big part of her life in helping people that suffered from blindness.

⁵ Jerzy Neyman (1894-1981). He was of Polish origin and studied Mathematics at the University Kharkov (Russia) and he did his PhD at the University of Warsaw. In 1938, he undertook as Chairman of the Statistics Laboratory in Berkeley, where in 1955 he founded the Department of Statistics. The six conferences that he organized there are really famous.

⁶ The legendary story of the unsolved problems in Statistics, was the inspiration source for the similar scene in the film "Good Will Hunting", (won Oscar for best writing 1998)



Figure 2. Dantzig was a founding member of The Institute of Management Sciences in the early 1950s.

In 1947, G.B. Dantzig contributed to the Mathematic Science by creating the ‘Simplex Method of Optimization’, which made him famous. It was the most noted and used method for the solution of a general Linear Programming problem. This method constitutes an algebraic repetitive process, which solves precisely every Linear Programming problem, in a finite number of steps. Thanks to the use of the Simplex method, he became more efficient in his work in the Martial Aviation, which helped him also to become an expert on planning methods that could be solved by using desk calculators.

By the time G.B. Dantzig created this new method, the term ‘Linear Programming’ did not exist. He used the term ‘programming’, a military term which at the time referred to the plans and programs concerning accountancy, military supplies, education and development of individuals. G.B. Dantzig mechanized the planning procedure by introducing a “Linear Programming in Structure”, where the term ‘programming’ is the aforementioned military term. The term ‘Linear Programming’ was suggested and finally accepted by ⁷Tjalling Koopmans during his visit at ⁸RAND Corporation in 1948, which was aiming at view exchanging. Linear Programming was tacitly used by ⁹Fourier in the early 1800s, but it was formally applied for the first time on economic problems, during the 1930s from ¹⁰Leonid Kantorovich, whose work was neglected in the West, since it remained literally hidden behind the ‘Iron Curtain’ and as a result remained unknown to the Western Europe and America. Tjalling Koopmans applied Linear Programming in problems regarding shipping, in the early 1940s. However, the first complete algorithm for the solution of Linear Programming problems with the name ‘Simplex Method’ was published by G.B. Dantzig in 1947.

⁷ Tjalling Charles Koopmans (1910-1985). Mathematician born in Holland. In 1975, he is granted with the Nobel Prize for the Economic Sciences, along with Leonid Kantorovich, “for their contribution in the theory of Optimum allocation of resources”. He is also known for the Koopmans Theorem, which is widespread in quantum chemistry.

⁸ The RAND Corporation (Research and Development). Non-profit think-tank with scientific, educational and philanthropic aims, always in favor of the public welfare and security of the United States of America.

⁹ Jean Baptiste Joseph Fourier (1768-1830). French Mathematician and Physicist, best known for initiating the research of Fourier Series and their application to problems of heat flow. Fourier is also credited with the discovery of the Greenhouse Effect.

¹⁰ Leonid Vitaliyevich Kantorovich (1912-1986). Born in Russia, studied Mathematics at the University of Leningrad, where he later undertook as a teacher. In 1965, he was awarded with the Lenin Prize and in 1975 with the Nobel Prize for the Economics Sciences, joint with Tjalling Charles Koopmans.



Figure 3. Left to right: Tjalling C. Koopmans, George B. Dantzig, Leonid V. Kantorovich. The photo was taken in Austria, in IASA - International Institute of System Analysis.

L. Kantorovich and T. Koopmans shared the Nobel Prize in Economics in 1975 “for their contribution to the theory of optimum allocation of resources”. Dantzig wasn’t nominated, although his work would justify such a prize. T. Koopmans wrote to L. Kantorovich, announcing him that he would deny the prize, as a protest towards the exclusion of G.B. Dantzig. L. Kantorovich, however, could not follow, because he saw the prize as a vindication for the use of Mathematics in Economics, which in the countries of the Soviet Bloc was “a means for the apologists of capitalism”.

The first extended use of the Simplex Method was made in order to determine the suitable and sufficient food supply the army with the minimal cost. In the fall of 1947, Jack Laderman of the Mathematical Tables Project of the National Bureau of Standards undertook the first large-scale computation in this field, as a test of the newly proposed simplex method. It was a system with nine equations in seventy seven unknowns, using manually-operated desk calculators and nine secretaries; it took 14 days of work, for finding a solution (roughly 960 man-hours). The particular problem had already been studied by ¹¹George Stigler, who suggested a solution based on the replacement of certain foods with others, resulting in the acquisition of more food per dollar. Then, he examined a total sum consisting of five hundred and ten possible ways of combining the selected foods. He did not believe that his solution was the optimum, though he strongly believed that the cost could not be decreased more than a few dollars per year. As a matter of fact, it was proved that Stigler’s solution, expressed in 1945’s dollars, was only 24 cents higher than the actual minimum \$39.69 per year.

Linear Programming was considered a revolutionary development, which gave man the ability to set goals and reach the optimum solutions in a category of practical problems, which were characterized by a certain complexity. Thereafter, G.B. Dantzig, referring to the functions of the Simplex Method, wrote: “The huge power of the Simplex Method is a constant surprise to me”.

In the course of time, many scientists have praised its possibilities. In particular, in 1980, Eugene Lawer wrote: “Linear Programming is used for the resources allocation, the planning of production, the timetable of working people, the planning of the portfolio investments and the formulation of marketing strategies. The variability and the economic impact of the Linear Programming, in the current industrial world, are really astonishing”. Furthermore, in 1991 M. L. Balinski wrote: “Mathematic Programming seems to have been blessed by at least two exceptional creative geniuses: By George Bernard Dantzig and Leonid Kantorovich”. The Simplex Method was declared as one of the ten most important algorithms of the 20th century by the Institute of Electrical and Electronic Engineers.

A typical example of a problem that can be solved using the Simplex method is the ‘diet problem’, which is presented below, in a simple form:

¹¹ George Stigler (1911-1991). American Economist, who taught in many Universities on the USA. He was honored with the Nobel Prize for the Economical Sciences in 1982.

Diet Problem: Dual Problem

“A dietician is preparing a meal consisting of chicken and rice. Each portion of this meal should contain at least 5 grams of proteins and 10 millionths of a gram of iron. Each chicken dish contains 5 grams of protein, 5 millionths of a gram of iron and 2 grams of fat. Each rice dish contains 1 gram of protein, 3 millionths of a gram of iron and 2 grams of fat. It is required that each portion contain the minimum fat amount. Find the number of chicken dishes and rice dishes that should be served, so that each portion contains the minimum amount of fat.”

By using the Simplex Method, we are led to the optimum solution of the problem, according to which each meal should consist of 0.5 portions of chicken and 2.5 portions of rice, so that the restrictions set in the problem to be fulfilled.

In between, in June of 1947, the Air Force established a major task force to work on the high-speed computation of its planning process, later named Project SCOOP (Scientific Computation of Optimal Programs), with George Bernard Dantzig as chief mathematician. He stayed with Project SCOOP until June 1952, when he joined the RAND Corporation as a research mathematician.

What is more, the systematic growth of the practical methods of calculating for Linear Programming basically begins in 1952 from the Rand Corporation, in Santa Monica, under G.B. Dantzig's guidance. He worked intensively in this program until the end of 1956, while in the meantime great progress had been made in the development of the first generation computers. During that time, along with the researcher Philip Wolfe, they develop the method *Dantzig-Wolfe* decomposition, which is used in order to simplify the important problems in programming and operation research, which include a vast number of data.

In 1960, he feels that the RAND Corporation is no more a source of new ideas and tries to find a way out of his uneasiness. He returns to Berkeley, as a professor of Engineering at the University of California and becomes a chairman of the Operations Research Center (1960-1966). In this way, he begins a brilliant academic career. He becomes a Professor of the Operations Research and Computer Science at the Stanford University (1966-1973). He is appointed Chairman of the CA Criley Endowed Chair in Transportation (1973-1985). He becomes a co-manager of the Systems Optimization Laboratory (1973-1998) and manager of the PILOT Energy-Economic Model Project (1975-88). He also teaches at the University until 1997, without quitting his research work.

During his academic career, he exhibited the best possible implementation of Linear Programming. He was generally involved with the formulation and resolution of management problems in most of the greatest industries, with the resolution of strategic and regular problems in defense, with the evaluation of plans and operational solutions for the better possible exploitation of energy and other resources, on a national and worldwide level, as well as with the theoretic progress of Mathematics, Statistics, Economics, Game Theory, and Computer Science. He also worked for the adopting of the model of Linear Programming, in a number of Mathematic Programming problems. G.B. Dantzig worked as an advisor in many big companies.

In 1963, his book “Linear Programming and Extensions” is published, and is commonly considered classic and impressive work of high scientific level, also pleasing to read. The readers of this book, students and researchers, get to know the basic elements of Linear Programming, a historical flashback of how this certain field began to develop, as well as the notable Mathematics applied for its extension. The book quickly became ‘the bible’ of linear programming. In a recently published two- volume edition (1997 – 2003), G.B. Dantzig and Mukund Thapa worked together on a brief review on the current functions of Linear Programming. In 1973, in his book, “Compact City: A Plan for a Liveable Urban Environment”, joint with Thomas L. Saaty, presents another view of G.B. Dantzig's wide-range of interests. The book is “a nontechnical, introductory study about the feasibility of building a city that makes more effective use of the vertical dimension and the time dimension (through around-the-clock use of facilities) than present cities do”. It includes a section on “Operations Research and the Total-System Approach”, but no linear programming!

G.B. Dantzig received many great honors and awards throughout his lifetime, some of which are the following:

- War Department Exceptional Civilian Service Medal in 1944.
- Member of the National Academy of Sciences in 1971.
- Von Neumann Theory Prize in Operational Research in 1975.
- The National Medal of Science presented by the President of the United States, Gerald R. Ford, in 1976, “for inventing linear programming and discovering methods that led to wide-scale scientific and technical applications to important problems in logistics, scheduling, and network optimization, and to the use of computers in making efficient use of the mathematical theory”.

- The National Academy of Sciences Award in Applied Mathematics and Numerical Analysis in 1977, “for the pioneering development of the theory and application of Programming, Operations Research and the Mathematic modeling of Economics”.



Figure 4. Left to right: George Dantzig, Anne Dantzig, President Gerald Ford (National Medal of Honor ceremony, 1971).

- The Harvey Prize in Science and Technology from Technion, Israel, in 1985, “in recognition of his outstanding contribution to engineering and the sciences through his pioneering work in mathematical programming and his development of the simplex method. His work permits the solution of many previously intractable problems and has turned linear programming into one of the most frequently used techniques of modern applied mathematics”.
- Member of the National Academy of Engineering in 1985.
- The Silver Medal from the Operational Research Society of Britain in 1986.
- The Adolph Coors American Ingenuity Award Certificate of Recognition by the State of Virginia in 1989.
- The Special Recognition Award from the Mathematical Programming Society in 1994.



Figure 5. George Dantzig congratulates the recipients of the Dantzig Dissertation Award 1999.

The Institute For The Operations Research and the Management Sciences (INFORMS), honored G.B. Dantzig by enacting the ‘George B. Dantzig Award’, which is awarded for the best innovative doctorate thesis in the field of Operational Research and Management Sciences.

He was a founding member of The Institute for Management Sciences and in 1966 became Chairman, too.

Throughout his career, he worked with:

- Econometric Society
- Institute of Mathematical Statistics
- Association for the Advancement of Science
- American Academy of Arts and Sciences
- Institute for Operations Research and the Management Sciences

G.B. Dantzig authored or co-authored seven books and more than 150 papers. Some examples are:

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He lived with Anne for 69 years. They had three children, David, Jessica and Paul. They also had three grandchildren and two great-grandchildren.

He died at an old age leaving behind invaluable legacy, on May 13, 2005, due to complications from diabetes and cardio vascular disease, at his home, in Palo Alto, California. He was 91 years old.

The scientific and economic impacts resulting from Dantzig's work are immeasurable. He will be warmly remembered in the years to come by those who were privileged to know him. To others, he will be known only through his work and its impact, far into the future. He also left as a legacy, his 50 students who did their doctorate under his guidance and supervision, in Berkeley and Stanford, and moreover the remembrance of being a good friend and a good teacher. Although his lifetime work has been globally recognized, he was unfairly deprived the greatest of all honors for a man of his magnitude, the Nobel Prize.

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