Mathematical Management –The History of Operations Research in the U.S., Western Europe and Germany

Queuing in front of a toll bridge in Chicago 2008 – a research domain of Operations Research.
Foto by Warren Black, 2008, at Flickr.com. Licence according Creative Commmons.

Working Paper on the History of Computing No. 6/2019

Richard Vahrenkamp
Logistik Consulting Berlin
Email: vahrenkamp2016@gmx.de
Web: www.vahrenkamp.org

Section 10 was published in Richard Vahrenkamp, Nominal Science without Data: The Cold War Content of Game Theory and Operations Research, in: Real World Economics Review, vol. 88, 2019, pp. 19–50. Section 11 was published in Richard Vahrenkamp, Mathematik trifft auf Machtkalkül. Kybernetik und Operationsforschung in der Reformära der DDR 1962–1970, in: Zeitschrift des Forschungsverbundes SED–Staat, issue 44/2019, pp. 152–167. A short version of this paper is published in the journal Management Revue under the title “Mathematical Management” in 2023, vol. 34, issue 1, pp. 69–91.

Translated from German by the AI software DeepL

Status: 14 July 2023

Content

Summary

The rise of Operations Research, which provides mathematical models for the management of commercial enterprises, in the political knowledge culture of Cold War Science is shown and then transferred to the institutionalization of Operations Research in Europe and in the Federal Republic of Germany. The predecessor organizations of the German Society for Operations Research are presented and the interaction of the annual conference of this society with the conferences on a European and worldwide level. It tells how numerous chairs for corporate research and operations research were founded at universities between 1960 and 1980. The connection between Operations Research and the macroeconomic field of econometrics in chairs, conferences and publications is explained and problematized. The

great flood of publications on the subject of Operations Research between 1960 and 1980 is referred to, but the rise of the competing field of business informatics in the 1980s halted the success of Operations Research. Based on the historical study by Alexander Nützenadel, the difference between the field of econometrics, which is based on empirical data, and the field of operations research, which is more academically oriented, is worked out. The methodological approach of Operations Research is referred to as abstractification. An example for abstractification is the transportation model of linear optimization, which simplifies (abstractifies) economic reality to such an extent that it can be transformed into manageable formulas. However, the transportation model is unsuitable for applications in the real economy and thus serves only as a self-referential project for the academic sector. This contribution shows that Operations Research lacks the level of empirical implementation of mathematical models known from econometrics and the social sciences. How transport optimization was taken up in the political knowledge cultures of the Eastern bloc (1945 - 1990) and in the German Democratic Republic is dealt with in section 12.

1 Introductory remarks

This paper shows how the field of Operations Research (OR) has emerged in the political knowledge culture of the Cold War since 1945. First the rapid institutional rise in the social spaces of universities is illustrated, but then the low degree of empirical projects in the social spaces of commercial enterprises is described and reasons given. At the same time, the rapid proliferation of computers for corporate management has hindered the implementation of OR projects in companies. The decline of Operations Research in the social spaces of universities began in the 1990s, when more and more chairs were rededicated to business informatics and logistics.

As Alexander Nützenadel noted in 2005 in his historical scientific study "The Hour of Economists" on economics, econometrics and scientific policy advice in the Federal Republic of Germany (FRG) in the 1950s and 1960s,[1] the period 1950 – 1965, which was fundamental for the political and economic emergence and establishment of the FRG, had so far been little researched. In this paper I take up the approach of Nützenadel and extend its investigation from economics to the historization of mathematical planning procedures in economics and business administration in the Federal Republic of Germany.

---

[1] Nützenadel, economists, 2005.

The Operations Research chairs are located in universities' business administration departments and deal with mathematical methods for the planning of material flow systems in factories, for the circulation planning of means of transport and for the creation of personnel deployment plans.[2] The research guiding ideas are the minimization of costs or the maximization of profits of an individual company. The cost and profit amounts are linked by definition via the turnover of a company as follows: Profit = Turnover - Costs. Costs or profits are modeled as a function of variables, and the minimum or maximum of this function is attempted to determine. In so-called linear programming, these functions are modeled as linear functions of the sets used and become the object of algorithms when they are minimized or maximized by complex structures of constraints, mostly expressed by linear inequalities, by compact sets in the n-dimensional number space. Often the algorithms have a loop structure of the form Repeat ... Improvement step ... until termination condition.

So far, the publications on the history of Operations Research have been rather uncritical success stories, such as the "Timeline" by Saul Gass and Arjang Assad from 2005, William Thomas' history of OR 2015 or the history of the OR by Stephen Johnson from 1997,[3] while the aim of this paper is to examine the field of Operations Research from the point of view of the history of science and to point out the social spaces in the Cold War science of the U.S., but also in the Eastern Bloc, in which the algorithmic knowledge cultures of Operations Research emerged. For evaluation purposes, a new approach is used to characterize the OR as a mathematical discipline based on the development of new mathematical methods, but less interested in obtaining empirical data.

If one compares Operations Research with the empirical sciences of econometrics, meteorology, astronomy and engineering, the OR's approach becomes clear. Atsushi Akera and Brent Jesiek have already highlighted the leading role of mathematicians in the development of the electronic digital computer.[4] I would like to take up this kind of argumentation and show that Operations Research also provides a mathematician-driven view of the world that uses new mathematical methods to develop abstract models of the economic and social structures of society.

In the engineering sciences, econometrics, astronomy and meteorology, mathematical models are used to structure measured data in order to make better predictions. Computers are loaded with data to test models. The scholars work within the triangle data–model–computer

---

[2] Operations Research is also abbreviated to OR and is also known in German as corporate research.
[3] Gass/Assad, Timeline, 2005. Johnson, Approaches, 1997.
[4] Akera, Calculating, 2007. Jesiek, Origins, 2013. On the early history of the digital computer see also Rojas / Hashagen: The First Computers, 2000.

and thus make this approach a data-driven one.[5] Numerous contributions in the literature show the emergence of mathematical models in meteorology, the collection of data in this field and their evaluation on computers in John von Neumann's group at the Institute for Advanced Study in Princeton from 1945 to 1955.[6] Gabriele Gramelsberger's contributions also demonstrate the empirical relevance of the branches of science biology and meteorology. The scientists mostly have personal experience with the material they are studying, as Nathan Ensmenger has shown using the example of laboratories in biological research.[7] Alexander Nützenadel demonstrated in his historical study the role of empirical economic data in the application of mathematical econometric models of the economy as a whole for forecasting economic development.[8]

However, the empirical reference to other scientific disciplines outlined here is missing in Operations Research. Heiner Müller-Merbach, Professor of Operations Research in Darmstadt, had already critically pointed this out in 1981, and this paper follows his approach.[9] Without an empirical research approach, the OR converts and abstractifizes economic relations into mathematical models that provide material for academic practice and merely represent a value in itself, but do not serve to solve social and economic problems. Simplified mathematical formulas are used to create beautiful models for academic use, as shown below in the example of the transport model. It was simplified so much that it could not be applied in empirical contexts at all. However, it could provide material for courses and for countless publications on the subject. Also, the modeling of dynamic material flow processes in the manufacturing industry with Markov processes, which cut off the history, leads to beautiful formulas. But the OR promoter Rudolf Henn had to admit in one of his publications that industrial processes do not have a truncated history, but the Markov approach leads to beautiful formulas.[10]

Operations Research is therefore not data-driven, but driven by new mathematical methods and belongs to the field of applied mathematics. This reference to applied mathematics is also seen by professors for OR, such as the leading OR promoter Hans Künzi, who held a chair for OR at the University of Zurich. In his opening lecture at the annual conference of the German

[5] Gramelsberger, Science, 2011.
[6] Thompson, Weather 1957. Aspray, Neumann, 1990.
[7] Ensmenger, Construction, 2012.
[8] Nützenadel, economists, 2005.
[9] Müller-Merbach, Empirical Research, 1981.
[10] Lecture at the founding meeting of the SVOR in 1961 by Rudolf Henn: Wirtschaftliche Anwendungsmöglichkeiten stochastischer Prozesse, in: Industrielle Organisation, Volume 31, 1962, Issue 1, pp. 19-24, here p. 19. In Volume 4 of Operations Research Verfahren, 1967, Bernd Goldstein published on more than 300 pages a confused paper with mathematical formulas for Markov chains without a single line of text.

Society for Operations Research in 1971, he stated: "One does not go wrong if one regards the theory of the new branch of research as a subfield of applied mathematics".[11] Unlike in the data-driven sciences described above, the researchers had no personal experience with the material of their field. Empirical data was not the focus of OR, and therefore the triangle data–model–computer often remained unused. The paper shows that the OR lacks a level of empirical implementation of mathematical models, such as those known from econometrics and the social sciences, and that this level has not been the subject of textbooks or research efforts in the field of operations research.

It should be emphasised that the process of modelling simplifies social reality to the extent that mathematical formulae can be applied at all and any necessary data collection is also simplified, as shown below using the example of the Berlin Air Lift. However, all models, even in the above-mentioned disciplines of engineering, econometrics, astronomy and meteorology, simplify reality. In contrast to the OR, however, the results of the model calculations are again applied in the real world. Examples are known from physics of how researchers simplify matter into a collection of vibrating atoms, as Max Planck did for his radiation formula and Albert Einstein for his theory of specific heat. However, these drastic simplifications in the models were countered by important results. Planck was able to derive his radiation formula using this approach, and Einstein was also able to explain the behavior of specific heat at low temperatures using this model.[12] However, the OR lacks this reference to reality, as this article shows using the example of the transport model.

2 The Origin of Operations Research in the Cold War Context

This section shows how Operations Research originated in the political knowledge culture of the Second World War and the subsequent Cold War. Many studies have already shown how operations research in the political knowledge culture of the U.S. and Great Britain emerged during the Second World War and the subsequent Cold War.[13] During the Second World War, Operations Research was developed in Britain and the U.S. to investigate methods for detecting enemy aircraft and submarines. Great Britain founded the group for Naval Operational Research and the U.S. the Antisubmarine Warfare Operations Research Group (ASWORG). After the Second World War, OR research did not break off, but the U.S.

[11] Künzi: Corporate Research, 1971, p. 3.
[12] Föhlsing, Albrecht: Albert Einstein – eine Biografie, Frankfurt 1995, p. 142, 175.
[13] Erickson u.a., How Reason 2013. Klein, Cold War 2015. William Thomas, Rational Action 2015, Krige, Hegemony 2006.

maintained special OR knowledge with the Navy Operations Evaluation Group, albeit with a reduced team. This group further developed the OR methods during the Cold War.[14]

In the social spaces of the mathematical departments in the U.S. armed forces, mathematicians strongly supported the development of the digital computer and related research in game theory and operations research. The Army's Ballistic Research Laboratory in Aberdeen, Md., was led by mathematicians and funded the development of the first electronic digital computer ENIAC at the Moore School of the University of Pennsylvania in Philadelphia. The Navy maintained a Naval Research office in Washington, D.C. with a mathematics department and supported numerous research and development projects.[15] The Air Force also operated the RAND Corporation (in Santa Monica near Los Angeles) with a Department of Applied Mathematics and the National Bureau of Standards (in Washington, D.C.) as agencies to finance and develop the digital computer, Operations Research and Game Theory. In the National Bureau of Standards, computer development was led by the Department of Applied Mathematics, which published a series of books on applied mathematics. The RAND Corporation was founded in 1948 in Santa Monica by the Air Force and was regarded as their think tank.[16] Research there focused not only on the future of air warfare and strategic bombing, but also on academic activities. RAND organized conferences and published books. As a newly formed branch of the military in 1947, the US Air Force (previously part of the US Army) sought to make a name for itself by applying scientific methods to the programming and use of the digital computer - which was only expected in the future - for this task, as a Chief of Staff Circular of 13 October 1948 put it.[17]

The invention of linear programming was made independently by the Russian mathematician and later Nobel Prize winner Leonid Kantorovich in 1939 and the US mathematician George Dantzig in 1947 at RAND in the context of Cold War Science. Before Linear Programming was developed as a mathematical optimization method in the RAND Corporation, Kantorowitsch developed his Linear Programming Approaches in 1939, which had remained unknown in the U.S. until 1960.[18] In 1947, RAND started the SCOOP project, which was intended to produce planning documents and forecasts for the demand for spare parts and fuel for the various aircraft types on the worldwide Air Force bases. This project has already been described in

---

[14] Harris, Center, 1996, p. 62-64. Shrader, History, 2013, chapter one.
[15] Rees, Computing, 1982, pp. 102-120.
[16] Shrader, History, 2013, p. 60. For RAND Corporation see Edwards, World, 1996, p. 114–116. George Dantzig: Impact of Linear Programming on Computer Development, Lecture at ORSA/TIMS meeting on April 30, 1985, typewriter manuscript Stanford University, Document ADA157659, 1985 (Internet source). For RAND see Bhattacharya, 2022, chapter 7.
[17] Paul Erickson et al., How Reason Almost Lost Its Mind, 60. On the history of RAND, see also the official presentation 50 Years Project Air Force, 1996.
[18] The English translation can be found in Kantorowitsch, Methods, 1960.

various historical analyses of mathematization.[19] The aim of this project was to accelerate the planning steps for a military operation, the so-called programme. In expectation of the electronic digital computer, the use of mathematical planning methods should shorten the program steps. The RAND mathematician Georg Dantzig invented a mathematical planning approach in 1947 and called it Linear Programming. It provided calculation techniques to maximize a linear function over a convex and compact set in the n-dimensional number space spanned by linear inequalities. The RAND Corporation owned numerous CPC-IBM machines, and Dantzig programmed, but not until 1952, his SCOOP optimization problem with 45 variables on this machine to identify the minimum cost of worldwide spare parts supply for the Air Force. After 8 hours he got the result. In 1952, he also coded this problem on the Univac I high-speed digital computer.[20] Among Dantzig's numerous research memoranda, applications of his model in the SCOOP project, which was to coordinate the Air Force's repair capacity worldwide, remained unknown. Dantzig's work at RAND seemed to be academic and without applications. The head of the SCOOP project, Murray Geisler, estimated that the Air Force's requirements were too extensive to be treated as a linear programme of the time in terms of scale.[21]

Independently of Dantzig's efforts, other scholars working on the SCOOP project have already been able to make decisions using methods other than linear programming to assemble air-transportable emergency crates of key spare parts, which are then distributed across all Air Force bases worldwide. It is remarkable from the point of view of scientific history that the development of linear programming was not marked by the expectation, otherwise expressed by economists, that economic science would be able to make similarly exact predictions to those in physics. These expectations motivated many mathematical economists in the 1940s, as Alexander Nützenadel pointed out in his investigation.[22]

As a showcase project for linear programming in the political knowledge culture of the US Air Force in the context of the Cold War, the SCOOP group also developed a model for the Berlin Airlift of 1948-1949 (Operation Vittel) and made it public at various conferences. Based on the wide range of aircraft models used in the Berlin Airlift, the project abstractified the aircraft

---

[19] For the SCOOP Project see Ceruzzi, Limits,1989, p. 41–43. Dantzig, Impact,1985, p. 15. Dorfman, Discovery, 1984. Geisler, History, 1986, p. 3–17. Johnson, Approaches, 898. Erickson, Mind, 72. Klein, Cold War, 2007.
[20] Orchard-Hays, History, 1984, p. 300. For Dantzig's coding work, see also Dantzig, Impact, 1985 , p. 26. For CPC machines, see Bashe et al., IBM's, 1986, p. 71.
[21] Geisler, History, 1986, p. 5. I am talking here about digital high-speed computers in order to distinguish the use of electronic analog computers, which were common in the US aviation industry for solving differential equations, see Vahrenkamp, Computing Boom, 2019. Professor Jürgen Heinhold of the University of Munich applied in 1962 for a DFG project on application possibilities of the electronic analog computer to problems of nonlinear optimization, see Brusberg, Unternehmensforschung 1965, p. 313.
[22] Nützenadel, economists, 2005, p. 91.

fleet and considered only C7 and C47 aircraft. It determined the most cost-effective schedule, taking into account fuel costs, crews and spare engines. The model was never used in daily planning, but served as a tutorial example to demonstrate the benefits of linear programming. It attracted academic attention, and some dissertations on this model were written. Murray Geisler, the head of SCOOP, suspected that the air force's requirements were too extensive and exceeded the scale that a linear programme could handle at the time by a high speed digital computer with a tiny memory of that time. He assumed that 3600 variables and 3600 inequalities would be necessary.[23] The linear programming model for the airlift can serve as a prime example for the thesis of abstraction I advocate. This model depicted the airlift only for the academic arena, but it served neither to prepare nor to control the airlift.

Since in 1947, when Dantzig invented the method of Linear Optimization, a digital high speed computer was not yet available, but small models of Linear Optimization had to be calculated on table calculators, as shown below under 11.4 also at the example of the Diet problem, where Danzig used the digital high speed computer for the Diet problem only in 1953, these considerations indicate that Dantzig had not conceived the method of Linear Optimization for the digital high speed computer at all. Also, the enthusiasm of the OR community for paper-and-pencil methods, discussed in more detail in Section 11.5 of the Transportation Model, indicates that OR was not even conceived in the context of the high-speed digital computer until the 1950s. Ignoring the computer even became the hallmark of the OR community, whose publications in the textbooks had not made any computer reference until 2010. It was understandable that in the late 1950s, when there was little computer capacity at U.S. universities, researchers helpfully turned to methods that could bypass actual computer use. These were the Monte Carlo method and the transport model. The use of the Monte Carlo method, however, mutated into the publication of tables of random numbers in print media from which researchers could draw. This turn to print media is particularly ironic since the Monte Carlo method was originally developed for the digital computer by John von Neumann.

As Nutzenadel had established in his investigation, the economists of the 1940s had a widespread idea that mechanical analogies, such as hydraulic machines, were to be sought for processes in the national economy. This also included the statistical determination of material flows between economic sectors, which were then formalised into input-output tables that reflect all upstream supply relationships.[24] In the Bureau of Labour Statistics of the U.S. Wassily Leontief collected data for an Input-Output-Matrix of the U.S. and gained a high scientific reputation. But this matrix, let's say A, with 200 rows and 200 columns, could only be

[23] Murray Geisler, A Personal History of Logistics, 6. Marshall Woon and Murray Geisler, Development of Dynamic Models for Program Planning, 1951. For operation Vittel see Paul Erickson et al., How Reason Almost Lost Its Mind, 2013, p. 56s.

[24] Nützenadel, economists, 2005, pp. 104–108.

used with a high-speed digital computer that was not available until the mid-1950s. To use the table, the "Leontief Inverse" matrix $(I–A)^{-1}$ had to be calculated, which was only possible with a computer.[25] Wassily Leontief's research also influenced SCOOP. In Project SCOOP, Dantzig expanded the matrix, known as inter industries relations, to 400 industrial sectors,[26] whose Leontief inverse could not computed by high speed digital computers at that time due to their tiny main memory. What is remarkable from the point of view of scientific history is how the SCOOP Group oscillated between local optimisation in a company or an organisation such as the Air Force and the macroeconomic level of the economy. Ideas on central economic planning ("market socialism") were discussed, which have asserted themselves in their enemy country – the Soviet Union. Under market socialism, the companies worked independently of each other, but the prices of the goods were calculated by a central computer ('super brain').[27] As a member of SCOOP, George Dantzig at the 1949 Activity Analysis Conference pointed out, like a Soviet planner, that Leontief's model could answer the central planning question of how much aluminum, steel, and electrical energy would be needed to meet the demands of increasing weapons production.[28] As Nutzenadel critically remarked, however, it remained open whether the input-output tables merely represent an impressive collection of statistics or whether they provide a useful basis for economic policy decisions.[29]

3 The transmission of the linear programming to other mathematization approaches

This section shows the rise of linear programming in the knowledge cultures of game theory and economics. When Dantzig presented his discovery of linear programming to John von Neumann in 1947, Neumann's mathematical genius was able to quickly make connections between linear optimization and two-person zero-sum play and also develop the duality theory of linear optimization.[30] Each linear program has a dual program with dual variables that uses the transposed coefficient matrix of the primal program. When solving the primal program, the dual program is implicitly solved at the same time. This primal-dual view

[25] Frederick Moore, "A Survey of Current Interindustry Models", in National Bureau of Economic Research, 1955, 215-252. For the calculation time of matrix inversion on different machines see Gass, Programming Shoppe, 2002, 62.
[26] Dantzig, Operations Research in the world, 1967, p. 115.
[27] Dorfman, Robert, Paul Samuelson and Robert Solow, Linear Programming and Economic Analysis, New York, 1958, 395. This book appeared under copyright of the RAND Corporation. Philip Mirowski, Machine Dreams, 259.
[28] Marshall Woon and George Dantzig, "The Programming of independent Activities", in: Koopmans 1951, 15–18, here 18.
[29] Nützenadel, economists, 2005, p. 108.
[30] Dantzig, Impact, 1985. Von Neumann/Morgenstern, Theory, 1944. Morgenstern, Collaboration, 1976. Henn/Moeschlin, Mathematical, 1977. Oskar Morgenstern took over a lectureship at the chair of Professor Rudolf Henn at the University of Karlsruhe in 1973.

considerably expanded the knowledge culture of linear programming. Whereas in the classical simplex algorithm the primary variables are always kept in the admissibility range, i.e. they are not negative and lie in the range of the admissible solutions of the polyhedron, in the dual program the dual variables are transferred step by step into their admissible range in parallel, so that at the end both the primary and the dual variables are admissible. Various algorithms are based on this primal-dual approach. The algorithm for the transport model examines how it can improve existing primary solutions by identifying attractive dual variables. The assignment problem as a specialization of the transport model proceeds differently. There, the dual variables are kept within the admissibility range at each step, while the primal variables are gradually transferred to the admissibility range.[31] The transport model radiates mathematical beauty, and intellectually and the “game” with primary and dual variables is very fascinating.

Economics has also taken up the primary and dual approaches. In the economic models, primal models are quantity-oriented, while dual models provide corresponding price information. In economics, linear programming could provide models that could be applied to production with linear production functions, to general equilibrium theory, to welfare economics, and to the theory of duopolies. In this respect, linear programming developed into an important component of the static equilibrium models of neoclassical theory. The famous economists Robert Dorfman, Robert Solow and Paul Samuelson were grateful to the RAND Corporation that Linear Programming was considered a fruitful analytical tool and in 1958 supported the publication of their book "Linear Programming and Economic Analysis", as they wrote in the preface. This publication in the RAND Books Series was very influential in that an international student edition also appeared.

4 The successful institutionalization of Operations Research 1950 - 1980 in the U.S., Europe and West Germany

This section deals with the political knowledge cultures in which Operations Research emerged. This has already been researched by the group at the Max Planck Institute for the History of Science (MPI Group), which held a summer school on this topic in Berlin in 2010.[32] US Air Force projects have also driven the transition from military to civilian linear programming applications in administration and industry. RAND entered into agreements with

---

[31] Mattfeld/Vahrenkamp, Logistics Networks, 2014, p. 173.
[32] Erickson and others, How Reason 2013. Klein, Cold War 2015.

the Universities of Chicago and Pittsburgh to apply the mathematical planning procedures summarized under the term "Operations Research" in the civil sector with the mathematical economist Tjalling Koopmans, with Abraham Charnes and with Herbert Simon.[33] In 1949 – just two years after Dantzig's discovery – RAND organized the later famous conference on Linear Programming at the University of Chicago, announced as "Activity Analysis of Production and Allocation", followed by the first symposium in Linear Programming in Washington, D.C., under the joint patronage of the RAND Corporation and the National Bureau of Standards in 1951. Both conferences took place without any experience with high-speed digital computers, which were only available at RAND in 1953.

In the 1950s, the term Operations Research was used to describe heterogeneous mathematical methods such as game theory, dynamic programming, linear programming, warehousing, spare parts theory, queue theory, simulation and production control, which were used primarily in civilian industry. Scientific societies and journals on the subject of Operations Research were founded in the 1950s, such as the Operation Research Society of America (ORSA) in 1952 and the Institute for Management Science (TIMS) in 1953. Philip Morse, the head of the Weapons Systems Evalution Group of the Pentagon, became the first president of ORSA and attracted the companies of the military-industrial complex to ORSA, which soon had more than 500 members.[34] In the 1960s, ORSA reached the amazing number of 8000 members.[35] Consulting companies also founded OR groups, as William Thomas emphasized in his study. In 1953, Abraham Charnes and William Cooper published the first textbook on linear programming.[36]

This section deals with the social spaces that are described as the institutionalization of the OR by mathematicians in economics departments of universities. The creation of ORSA and TIMS was not based on industry demand for OR applications, but turned out to be an autonomous expert movement of mathematicians supported by military research institutions. The Office of Naval Research has published Naval Research Logistics Quarterly since 1953, which published models of battlefields and became the world's leading international journal for Operations Research in the 1950s. The Office of Ordnance Research of the US Army held its first OR conference in January 1955.[37] In his 1960 book on the automation movement, Herbert Simon characterized Operations Research as a new science of management driven by mathematicians.[38] The autonomous OR movement of mathematicians was not unusual for the

---

[33] Johnson, Three Approaches to Big Technology, 898. Paul Erickson et al., How reason almost lost its mind, 2013, 72. Klein, The Cold War Hot, 2007. Koopmans, Activity Analysis, 1951. Klein, Cold War, 2015.
[34] Krige, American Hegemony, 233s.
[35] Hanssmann, Corporate Research, 1971, p. 11.
[36] Thomas, Operations Research 2012. Charnes, Linear Programming, 1953.
[37] Churchman/Ackoff/Arnoff, Introduction, 1957, p. 429.
[38] Simon, Science, 1960, p. 15.

20th century. One can also place Taylorism in the context of various expert movements in the 20th century, as well as the rationalization debate in Europe in the 1920s and the automation debate in the U.S. and Europe around 1960.[39]

In the 1950s and 1960s chairs of operations research were established in the U.S. and Great Britain (from 1964 in Lancaster) in the management faculties of universities. Further influences from the U.S. on the development of Operations Research in Western Europe can be traced here. Thus authoritative OR textbooks from the U.S. were published in German and French (but not in Italian), such as the book by George Dantzig "Linear Programming"(1963) and the book by West Churchman at al. "Introduction to Operations Rese-arch"(1957). The latter was also published in Spanish in Madrid in 1973, opening at the same time Latin American readers to Operations Research. NATO gave important impulses for the spread of Operations Research in Western Europe. NATO headquarters SHAPE in France organised four conferences on OR in the 1950s - the one in 1956 with 120 participants - and thus brought OR to mainland Europe.[40] Within NATO, OR was also known as "Scientific Advisory" (SA) and was grouped together in the Advisory Group of Aeronautical Research and Development (AGARD).[41] Both NATO institutions, SHAPE and AGARD, organized an OR conference in April 1957 at the Palais de Chailott in Paris - one of the most prestigious conference venues in Paris.[42] If one reads the conference papers today, the Nato conferences stand out as extremely pale: There was a mutual assurance of the importance of OR. But the actual goals of NATO OR remained unmentioned: did they want to improve radar or the accuracy of anti-aircraft guns? How could the supply of spare parts be accelerated? When France left Nato, the transfer of Nato headquarters from France to Belgium in 1966 radiated to the institutionalization of OR in Belgium, where Jacques Drèze founded CORE, the Center for Operations Research and Econometrics at the Catholic University of Leuven (Belgium) in 1966.[43] As early as 1956, the newly founded Federal Ministry of Defence of the Federal Republic of Germany awarded three small projects, not on weapons development but on the methodology of OR, to the universities of Munich, Münster and Kiel.[44]

---

[39] Haber, Efficiency, 1964. Maier, Taylorism, 1970. Kline, Cybernetics, 2006.

[40] Operational Research in Practice, Report of a NATO Conference, herausgegeben von Max Davies und Michel Verhust, Pergamon Press London 1958, p. 1.

[41] The AGARD history: 1952 - 1997 / NATO. Advisory Group for Aerospace Research and Development ; Bliek, Jan van der [ed.]. - Neuilly-sur-Seine, 1999. For the export of OR to Europa by Nato see Krige, Hegenomy, Kapitel 8.

[42] Operational Research in Practice, Report of a NATO Conference, edited by Max Davies und Michel Verhust, Pergamon Press London 1958.

[43] NATO Conference on the Role and Evaluation of Military Exercises in Operational Research, London, England, 25 August 1964. Kirby, M. and R. Capey, The Origins and Diffusion of Operational Research in the UK, 1998. Brusberg, Unternehmensforschung 1965, p. 52.

[44] Benecke, Status of Operations Research in Germany, p. 23, in: Max Davies et al.: Operational Research in Practice, Report of a NATO Conference, London 1958.

The founding of an international umbrella organization for national OR societies in Oxford in 1959, the International Federation of Operational Research Societies (IFORS), described below, exerted considerable pressure in the German-speaking world on how the respective national OR initiatives in Austria, Switzerland and West Germany should relate to IFORS. Which organization should represent the German-speaking region in IFORS? Should Austrians or Swiss be represented by their own organization? The Swiss OR community responded to the IFORS challenge by founding its own Swiss Association for Operations Research (SVOR) in Zurich in 1961. At the founding meeting, various OR researchers gave lectures, including the later OR promoter in West Germany, Rudolf Henn, then professor at the Handelshochschule St. Gallen. The lectures were published in issue 11/1961 of the journal "Industrielle Organisation" published by the ETH Zurich and thus received an application context in industry.[45] Henn, together with Hans Künzi, a habilitated mathematician who was elected president of the SVOR, later edited a two-volume work on business research (OR). The Austrian OR community could not decide whether to found its own society or to be represented by the West German AKOR (Arbeitskreis Operational Research). The indecisiveness of the Austrians also led to a delay in AKOR being accepted into IFORS as the West German representative. That the GDR was not to be admitted to IFORS was clear, since IFORS was anti-communist from the outset and was to represent the free West. The GDR was not recognized as a separate state in the West anyway. The anti-communist orientation of IFORS was not predominant in the umbrella organization of national societies for computer applications, the International Federation of Information Processing (IFIP), which was also founded in 1959, since it also had members from the Eastern Bloc. However, Alwin Walther, representing the German Association for Computing Systems (DARA), insisted at the 1960 meeting of the Executive Committee of IFIP in Rome that the West German DARA also represent the eastern part of Germany.[46]

The foundation of the German OR societies clearly shows the division into practitioners and mathematicians. The AKOR was founded in February 1957 at the Institute for Practical Mathematics by Professor Alwin Walther of the TH Darmstadt at the instigation of the Committee for Economic Manufacturing (AWF) - associated with the Rationalisierungskuratorium der Deutschen Wirtschaft (RKW) based in Frankfurt a.M. - in the run-up to the international OR conference in Oxford (Great Britain) in September 1957, in order to obtain a platform for participation in this conference.[47] Although IFORS was not founded until 1959, the Oxford OR Conference counted as an IFORS precursor conference or even the first IFORS conference. RKW played the role of OR promoter in West Germany as

---

45 Ablauf– und Planungsforschung, Vol. 2, 1961, Issue 3, p. 66.

46 Minutes of the Exekutivkommittee under https://www.ifip.org//images/stories/ifip/public/Archive/MinHist/1960%20council%20jun%20rome%20(it).pdf.

47 Davies, Max (ed.): International Conference on Operational Research (Oxford), London 1957, p. 494.

early as 1955, when it organized a trip of five experts - including Helmut Kregeloh of the Institute for Practical Mathematics of the TH Darmstadt - to the U.S., financed by the Ministry of Economics, to explore the status of OR implementation in the U.S. among large companies.[48] The foundation of IFORS in 1959 led AKOR to professionalize its appearance by publishing the journal "Ablauf- und Planungsforschung" from 1960 on. AKOR was led by Helmut Kregerloh, a mathematician without a doctorate, but who had an academic background as an assistant to Alwin Walther at the Mathematical Institute of the Technical University of Darmstadt. AKOR turned mainly to the business field of consulting in order to spread the OR methods in the companies. Apparently, the consulting market was attractive, since the Technical Academy in Wuppertal also wanted to offer OR consulting. AKOR agreed with the Technical Academy that it should only offer courses lasting one to three days. Courses of longer duration were to be reserved for AKOR.[49] In order to cover the consulting markets in Austria and Switzerland, meetings of AKOR were also offered in the countries there, for example on October 22, 1959 in Salzburg.[50]

As vice-president of IFIP in 1960, Alwin Walther succeeded in bringing the second international IFIP congress to Munich in 1962. This congress was attended by the seemingly overwhelming number of 2800 professionals and made it clear to the German OR community that one should not limit oneself to mathematical models alone, but how important computer applications in production and administration were.[51] Numerous papers on this subject were published in AKOR's journal "Ablauf- und Planungsforschung".[52]

An appreciation of Alwin Walther on his 65th birthday with a portrait photo in the journal for "Ablauf- und Planungsforschung" bypassed his involvement in the NS regime.[53] The Institute of Practical Mathematics of Professor Alwin Walther, was scandalized because of its cooperation with the Nazi organization of the SS in 1944. Walther planned a concentration

---

[48] Rationalisierungskuratorium der Deutsche Wirtschaft (ed.): Ablauf– und Planungsforschung, Operations Research, Erfahrungsbericht einer deutschen Studiengruppe von einer Reise in die U.S., München 1958. Wie die Teilnehmer indirekt einräumten, waren sie methodisch überfordert, den Stand der Implementierung von OR in bei großen Unternehmen zu erkunden. Vielmehr referierten sie in der Buchpublikation verschiedene Methoden des OR, wie Lagerhaltung oder Warteschlangen, die sie aus den bekannten Veröffentlichungen zum OR entnahmen.

[49] Ablauf– und Planungsforschung, Vol. 2, 1961, Issue 1, p. 16.

[50] Unternehmensforschung, Vol. 4, 1960, p. 95.

[51] Tagungsbericht von Heiner Müller–Merbach, in: Ablauf– und Planungsforschung, Vol. 3, 1962, Issue 1, pp. 113–115.

[52] Alwin Walther: Der Rechenautomat und Operational Research, in: Ablauf– und Planungsforschung, Vol. 4, 1963, Issue 1, p. 146–157.

[53] Ablauf– und Planungsforschung, Vol. 4, 1963, Issue 1, p. 181.

[53] Ablauf– und Planungsforschung, Vol. 4, 1963, Issue 1, pp. 181–182.

camp for prisoners who were to perform mathematical calculations for the V2 rocket in forced labor, as research by Melanie Hanel only revealed in 2014. [54]

While primarily practitioners, i.e. employees or even executives of research and development institutions of large companies, were organized in the AKOR, mathematicians at universities took the lead in the "Deutsche Gesellschaft für Unternehmensforschung" (DGU). Compared to the practitioners, the mathematicians at university chairs tended to marginalize computer applications in the German Society for Enterprise Research. The foundation of the "Gesellschaft für Unternehmensforschung" (Society for Enterprise Research) in Munich in 1961[55] went back to the expert committee "Unternehmensforschung" (Enterprise Research), which was established in 1959 by the "Gesellschaft für angewandte Mathematik und Mechanik" (Society for Applied Mathematics and Mechanics) (GAMM) as a consequence of the foundation of IFORS at the Institute for Applied Mathematics of the University of Freiburg i. Br. with Professor Görtler as chairman. [56] This technical committee founded an umbrella organization of German societies for operations research - the "Deutscher Ausschuss für Unternehmensforschung" (DAU), in order to gain the German or West German representation rights for the International Federation of Operational Societies, IFORS, founded in 1959, at the second IFORS meeting in Aix-en-Provence in 1960. In fact, GAMM succeeded in sending a representative to Aix through AKOR. In order to gain academic weight, the "German Committee for Business Research" had organized a conference in Freiburg with speakers from abroad right in August 1960. Since the Freiburg research center of the "Deutsche Gesellschaft für Luft- und Raumfahrt" (German Aerospace Society) was a co-organizer of the conference, one can assume that federal funds were available to finance the not inconsiderable travel expenses of the foreign speakers. [57]

According to AKOR's 1960 report, AKOR was able to retain German representation rights vis-à-vis IFORS after discussions with the current president of IFORS, Sir Charles Goodeves, and with the future president of IFORS, Philip Morse. [58] Wilhelm Krelle, trained as a mathematical physicist and professor of economics at the University of Bonn since 1958, was on the board of the "Gesellschaft für Unternehmensforschung" and attracted many mathematicians to the DGU. Krelle was able to enforce vis-à-vis AKOR that the German registrations for lectures at the third IFORS conference in Oslo in 1963 went over his desk. [59] The DGU tried to win the eponymous journal "Unternehmensforschung" as its association organ. [60] Although, as a

---

[54] Melanie Hanel: Die TH Darmstadt im Nationalsozialismus, Darmstadt 2014.
[55] Ablauf– und Planungsforschung, Vol. 3, 1962, Issue 1, p. 14.
[56] Ablauf– und Planungsforschung, Vol. 2, 1961, Issue 1, p. 15. Unternehmensforschung, Vol. 4, 1960, p. 96s.
[57] Konferenzbericht in: Ablauf– und Planungsforschung, Vol. 2, 1961, Issue 2, p. 24.
[58] Ablauf– und Planungsforschung, Vol. 2, 1961, Issue 1, p. 16.
[59] Ablauf– und Planungsforschung, Vol. 3, 1962, Issue 1, p. 31.
[60] Ablauf– und Planungsforschung, Vol. 3, 1962, Issue 1, p. 15.

member of the board of the DGU, he was actually interested in corporate research, Krelle took the liberty of publishing a purely mathematical book on non-linear optimization without computer applications and without applications in companies, together with the habilitated mathematician Hans Künzi, with Springer publisher in 1962. The "Deutsche Gesellschaft für Unternehmensforschung" reached the number of 259 members in 1962. [61] In 1971, AKOR and DGU merged to form the German Society for Operations Research (DGOR), which has since held annual meetings and published the papers presented in annual proceedings. The number of personal members of DGOR grew from 496 in 1972 to over 600 in 1978. [62]

The journal "Unternehmensforschung" with the subtitle "Operations Research" was founded in 1956 by Slavcho Sagoroff, professor of statistics at the University of Vienna, completely independently of the DGU and published by Physica. [63] According to the editorial of the first number, the journal "Unternehmensforschung" was definitely application-oriented and not merely fixated on mathematical models. The editor assembled numerous prominent names on the journal's advisory board, including Alwin Walther and Oskar Morgenstern, who had worked in Vienna before his forced emigration. The journal also published numerous articles on the use of computers in production control. Apparently, Sagoroff coined the term "enterprise research." At the 27th annual meeting of the German Statistical Society in Essen in 1956, Sagoroff had further institutionalized the term "enterprise research" and had suggested in advance that the committee "Application of Statistical Methods in Industry" meet on the topic of "Enterprise Research in Manufacturing Companies." [64] Sagoroff tried to establish OR in Switzerland with a meeting at the ETH Zurich in 1958. [65] It is striking that the journal "Unternehmensforschung" did not cover OR initiatives in Austria at all. After the foundation of the "Deutsche Gesellschaft für Unternehmensforschung" in 1961, this society tried to take over the journal "Unternehmensforschung" as its organ.

What is striking about the numerous conferences on operations research in Germany and Zwitzerland in the 1950s and 1960s is the low content of new research results. In fact, in many cases merely results from England and the US are presented by the speakers, who should, if possible, also be from England and the US. At each new conference, the magic of mathematical methods for business practitioners was invoked anew, such as the Linear Planning Technique, the Transport Model and Monte Carlo Methods. In many cases, topics from the 1930s were also addressed and given the fresh label of Operations Research: Rudolf

---

[61] Brusberg, Unternehmensforschung, 1965, p. 56f, p. 242–244. Albach, Unternehmensforschung, 1967, p. 254.

[62] Bradtke, Grundlagen, 2003, p. 3. Deutsche Gesellschaft für Operations Research (ed.), Mitgliederverzeichnis, 1978, Niddatal 1978. Brusberg, Unternehmensforschung, 1965, p. 241.

[63] Adolf Adam: Slawtscho Sagoroff, Leben und Wirken. In: Metrika 14 (1969) 1, pp. 133-137.

[64] Unternehmensforschung, 1. 1956, issue 1, p. 63.

[65] Tagungsbericht in: Unternehmensforschung, 2.1958, p. 208.

Henn's lecture on Markov processes in industrial plants[66], Wilhelm Krelle's lecture on decisions in the presence of uncertainty at the founding meeting of the SVOR[67], lectures on queuing systems and inventory management. The book on nonlinear optimization published by Krelle and Künzi in 1962, which saw numerous reprints, also contained merely US results from the 1950s, but no new research by the two authors. The debate in England of the 1950s, referred to by John Krige, whether operations research was really new, did not take place in Germany. [68]

Surprisingly, the German computer pioneer Konrad Zuse or his computer production factory, Zuse KG in Hünfeld or Bad Hersfeld, published numerous articles in the Viennese journal "Unternehmensforschung". Konrad Zuse published the essay "Große und kleine programmgesteuerte Rechengeräte" (Large and small program-controlled computing devices) in volume 1, 1956/57. Furthermore, he published the text of his lecture at the award of the honorary doctorate at the TH Berlin on May 28, 1957: "Gedanken zur Automation und zum Problem der technischen Keimzelle " (Thoughts on automation and the problem of the technical germ cell), in volume 1, 1956/57. A note on the honorary doctorate with a photo of Zuse also appeared there. With his lecture text, Zuse took up the automation debate that was virulent in the US and Europe in the years 1955 to 1960. [69] Finally, Konrad Zuse KG published an article with the author Adolf Adam on the Z70 computer specially developed by Zuse KG to control production. The contribution in Volume 4, 1960 is entitled: "The Z70 as an information technology solution to a business organization problem". Although the Institute for Practical Mathematics of Alwin Walther at the Technical University Darmstadt is even located in the same federal state of Hesse as the computer factory of Konrad Zuse, Zuse never published in the journal of AKOR, in the journal for "Ablauf- und Planungsforschung."

In the 1960s, OR chairs were also established in Switzerland and the Federal Republic of Germany (BRD). As early as 1958, the habilitated mathematician Hans Künzi held an OR chair at the University of Zurich and from 1966 an additional parallel OR chair at the Swiss Federal Institute of Technology Zurich. Since 1962 he has been President of the Swiss Association for Operations Research (SVOR). In his opening lecture on "Operations Research in Science, Business and Politics" at the annual conference of the German Society for Operations

---

[66] Lecture at SVOR in1961 given by Rudolf Henn: Wirtschaftliche Anwendungsmöglichkeiten stochastischer Prozesse, in: Industrielle Organisation, Vol. 31, 1962, issue 1, pp. 19–24. Henn acknowledged that the Markov process model greatly simplifies manufacturing operations.

[67] Industrielle Organisation, vol. 30, 1962, issue 11, pp. 523–526.

[68] Krige, John: American Hegemony and the Postwar Reconstruction of Science in Europe, Cambridge (Mass) 2006.

[69] Richard Vahrenkamp: Von Taylor zu Toyota – Rationalisierungsdebatten im 20. Jahrhundert, Köln 2013.

Research in Bochum in 1971, Künzi reported on a project with the Swiss Ministry of Economics in which he modelled the cost-minimal allocation of arable land in Swiss agriculture using an optimisation model in order to ensure the supply of food to the Swiss population in the event of defence. To determine the optimal solution, the model ran for one hour on a high-speed digital computer. He also reported on a cost-minimized selection of a fighter aircraft for the Swiss military and the optimization of inner-city traffic light circuits.[70] However, these three examples lack industrial applications. From the title "Unternehmensforschung in Wissenschaft, Wirtschaft und Politik" ("Operations Research in Science, Business and Politics"), Künzi first refers to science and thus indicates the self-referential understanding of the social space of Operations Research.

Before an increased institutionalization of OR at universities began in the FRG in the 1960s, the Arbeitskreis Operational Research (AKOR) was founded in Darmstadt in 1957 and the Deutsche Gesellschaft für Unternehmensforschung (DGU) in Munich in 1961, whose membership reached 259 in 1962. These societies published the journals "Ablauf- und Planungsforschung" (five times a year) and "Unternehmensforschung" (four times a year) [71] AKOR was founded in February 1957 at the Institute for Practical Mathematics by Professor Alwin Walther of the TH Darmstadt at the instigation of the Committee for Economic Manufacturing (AWF) - associated with the Rationalisierungskuratorium der deutschen Wirtschaft (RKW) based in Frankfurt a.M. - in the run-up to the first IFORS conference in Oxford (Great Britain) in September 1957.[72] In 1971 AKOR and DGU merged to form the German Society for Operations Research (DGOR), which since then has held annual meetings and publishes its papers in annual proceedings. The number of personal DGOR members grew from 496 in 1972 to over 600 in 1978.[73]

---

[70] Künzi, Corporate Research, 1971, p. 8.
[71] Brusberg, Corporate Research, 1965, p. 56f, p. 242-244. Albach, Corporate Research, 1967, p. 254.
[72] Davies, Max (ed.): International Conference on Operational Research (Oxford), London 1957, p. 494. Professor Alwin Walther's Institute for Practical Mathematics was surrounded by scandal because of his cooperation with the SS in 1944. Walther planned a concentration camp for prisoners who were to perform mathematical calculations for the V2 rocket in forced labor, see Melanie Hanel: Die TH Darmstadt im Nationalsozialismus, Darmstadt 2014.
[73] 40 Reinhold Sellien, Helmut Sellien (eds.), Gablers Wirtschafts Lexikon, 10th edition, Wiesbaden 1980, column 1003f. Bradtke, Grundlagen, 2003, p. 3. German Society for Operations Research (Hersg.), Membership Directory, 1978, Niddatal 1978. Brusberg, Corporate Research, 1965, p. 241.

In 1963, there were already three institutes for Operations Research at universities in Germany:[74]

- Institute for Industrial Enterprise Research at the University of Münster, headed by Ludwig Pack, Professor of Business Administration.
- Institute for Econometrics and Operations Research at the University of Bonn, headed by Martin Beckmann, Professor of Economics, after working with the mathematical economist Tjalling Koopmans (see below) in the Cowles Commission at the University of Chicago.[75]
- Institute for Operations Research at the University of Hamburg, headed by Herbert Jacob, Professor of Industrial Management and Organization.

The boom in Operations Research observed by Thomas Bradtke[76] in Germany between 1960 and 1970 was given a considerable boost by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) when it included the field of corporate research in its priority programme in 1961. In 1962 and 1963, she financed 16 and 30 small-scale projects on Operations Research, respectively, with one to two man-years each, at the chairs of West German universities, which were predominantly set up in model theory without empirical reference, as the thematic list of all projects revealed.[77] The DFG commissioned a report on the state of Operations Research, which was published as a 400-page book in 1965. The author, Diplomingenieur Helmut Brusberg, recommended an extension of the DFG priority programme and the inclusion of "at least one mathematician" in the local OR research groups.[78] There was no mention of female mathematicians in the report. The Faculty of Economic Sciences at the University of Bonn benefited from the close proximity of the DFG headquarters in Bad Godesberg. Not only was a literature reference for OR in Bonn financed by the DFG, which already comprised 836 volumes in 1963.[79] In 1962 and 1963, the faculty was also able to acquire two and three small projects respectively in the OR priority programme: Professor Horst Albach, who played a leading role in business administration, received the model theoretical projects:

- Operational issues of investment policy,
- Applications of Dynamic Programming in Investment Theory and
- Scheduling and production planning.

---

[74] Brusberg, Corporate Research, 1965, p. 253.
[75] For the role of Tjalling Koopmans in the Cowles Commission see Mirowski, Machine, 2002.
[76] Bradtke, Basics, 2003, p. 2.
[77] Brusberg, Operations Research 1965, pp. 313-316.
[78] See also Albach, Unternehmensforschung, 1967.
[79] Catalogue of the Reference for Corporate Research, Institute for Econometrics and Corporate Research, University of Bonn 1963-1970, Institute for Econometrics and Corporate Research, Bonn, 1971.

And Professor Wilhelm Krelle received two self-referential projects from the DFG: "Promotion of Operations Research ."[80] Krelle graduated with a degree in physics and already played a decisive role in the OR network when the DGU was founded and as its chairman. On the macroeconomic level, he developed large econometric models of the German economy ("the Bonn Model") and became spokesperson of the DFG Collaborative Research Centre 21 "Economic Prognosis, Decision and Equilibrium Models" at the University of Bonn from 1970 to 1984. In subproject B1, he conducted research on mathematical econometric prognosis models of the economy as a whole.[81]

With an economic and mathematical education, Rudolf Henn occupied the Chair of Econometrics and Operations Research at the University of Karlsruhe in 1966 and became one of the leading OR promoters in Germany with his journal "Operations Research Verfahren" published since 1963. Volume 1, published in 1963, published the papers of the conference on OR procedures in industry held in Zurich on 9 and 10 December 1959. The conference was organized by the Research Center Operations Research and Econometrics of the University of Göttingen and the Institute of Business Administration of the University of St. Gallen.[82] Volume 2, published in 1965, contained the opening lecture by Henri Theil on "Econometrics and Operations Research ", which he gave at the joint meeting of TIMS and the Econometric Society in Zurich in September 1964, indicating the influence of TIMS in Europe and the link between the fields of OR and econometrics. With the publication of volume 3, the mathematician Burkhardt Rauhut, who holds a degree in mathematics, assumed the function of editor at the Henn Chair in the Institute for Economic and Social Sciences at the Technical University of Karlsruhe. In 1966, both Henn and Künzi jointly published the basic work "Einführung in die Unternehmensforschung" ("Introduction to Operations Research ") for university teaching in the Heidelberg pocket books of Springer Verlag in two volumes.[83]

Five newly created OR chairs in Germany indicate a successful institutionalisation of OR in the social spaces of universities in the period 1969 - 1981:

- Hans-Jürgen Zimmermann (Chair of Corporate Research) at the RWTH Aachen University in 1969. Zimmermann completed his studies in the mathematical models strongly influenced course of studies of the graduate engineer and received his doctorate in mathematical economics. Zimmermann introduced methods of fuzzy sets into the OR.

---

80 Brusberg, Operations Research 1965, p. 313s.
81 On Wilhelm Krelle see Nützenadel, Ökonomen, 2005, pp. 118-119.
82 For the history of econometrics, see Nützenadel, Ökonomen, 2005, pp. 91s.
83 Henn/Künzi, Introduction, 1966 with biographical data of Henn and Künzi.

- Christoph Schneeweiss (Chair of Operations Research) at the FU Berlin 1971. Schneeweiss received his doctorate in physics, a field strongly influenced by mathematical models. Schneeweiss was president of EURO from 1999 to 2000 (see below).
- Heiner Müller-Merbach, 1972 Professor of Business Administration and Operations Research at the TH Darmstadt. From 1961 to 1967 he was an assistant at the Institute for Practical Mathematics of the TH Darmstadt.
- Dieter Pressmer (Chair of Corporate Research) at the University of Hamburg in 1974. He completed his studies in the mathematical models strongly influenced course of the graduate engineer. Pressmer was President of the 9th World Congress of IFORS 1984 (see below).
- Wolfgang Domschke (Chair of Operations Research) at the Bundeswehr University Hamburg 1975. Domschke obtained his academic degrees at the Faculty of Economics of the Technical University Karlsruhe, which is strongly influenced by mathematics.
- Richard Vahrenkamp (Chair of Operations Research) at the University of Kassel in 1981. Vahrenkamp completed his studies at the University of Heidelberg with a degree in mathematics.

The boom in Operations Research observed by Thomas Bradtke in the Federal Republic of Germany continued after this constellation in the years 1970 to 1980.[84] The tendency to fill OR chairs at economics faculties primarily with mathematically trained applicants can only be stated here. The reason for the high reputation of this applicant category at the economic science faculties can only be explained by studying the archive holdings, where files of appointment procedures could provide information. One can generally assume a high reputation of the modern quantitative methods originating from the U.S. in Europe, which were also created and supported in the press by numerous picture reports about the arrival of large computers from the U.S. by air freight at airports in Germany and Switzerland.[85]

Hans Künzi and Martin Beckmann gained a dominant position in the German-speaking area of the OR research network (including Austria and Switzerland) when they published a softcover Lecture Notes series at Springer Verlag in 1968: The "Lecture Notes in Operations Research and Mathematical Economics", which were renamed "Lecture Notes in Operations Research and Mathematical Systems" from volume 15 onwards in 1969. It was renamed to "Lecture Notes in Economics and Mathematical Systems" in 1971 from volume number 60 onwards.

---

[84] Bradtke, Basics, 2003, p. 2.

[85] See the great press echo of the arrival of a UNIVAC computer at Frankfurt's Rhein-Main airport in a PAN AM cargo plane on August 6, 1956. The computer was destined for the contract research company Battelle in Frankfurt a.M., see Die Lochkarte – Hausmitteilungen der Remington Rand GmbH Frankfurt a. M., No. 168, 1956, p. 1973.

Künzi also used volume 1 of the OR series on decisions in cases of uncertainty as training material for the SVOR.[86] With these series, Springer Verlag opened up a new publication format based on the duplication of typewriter manuscripts using the offset process, thus avoiding the costly lead typesetting and enabling rapid publication after manuscript submission. The rows grew explosively. The series "Lecture Notes in Economics and Mathematical Systems" reached the number of 170 titles in 1979, i.e. 16 titles per year since 1968, as the editors documented in a special volume.[87] The other series already reached the number of 50 titles in 1970, i.e. also 16 titles per year.[88] Before the success of the Lecture Notes series, Hans Künzi and Wilhelm Krelle laid the foundation for the hardcover book series "Ökonometrie und Unternehmensforschung" at Springer Verlag. Volume 1 was Künzi/Krelle/Oettli: Nichtlineare Programmierung, 1962, then four years later Volume 2 was published in 1966 with the German translation of Dantzig's book "Linear Programming and Extensions". Within 10 years, 20 more volumes followed.[89] The dictum "Hour of the Economists", coined by Alexander Nützenadel, seems to apply to the 1970s, considering the rapid expansion the Lecture Notes series and Künzi’s and Krelle’s hard-cover series.

[86] H. Bühlmann and others: Introduction to the Theory and Practice of Decision in Uncertainty, Berlin 1968, second edition 1969.

[87] Beckmann/Künzi 1979.

[88] Beckmann, Operations Research Today, 1971, Directory of Titles.

[89] A list of the published volumes is printed in Burkhard/Derigs: Assigment und Matching Probleme, 1980, backcover. Even before the Lecture Notes series, the Akademieverlag in Eastberlin published the protocols of the conference "Mathematics and Cybernetics in Economics" in a similar format to the Lecture Notes series already in 1965: Softcover, offset printing to enable rapid publication, as the foreword emphasized, and a colored, distinctive crossbar on the title (cf. figure 3). Apparently, this publication served as a model for the Lecture Notes serie.

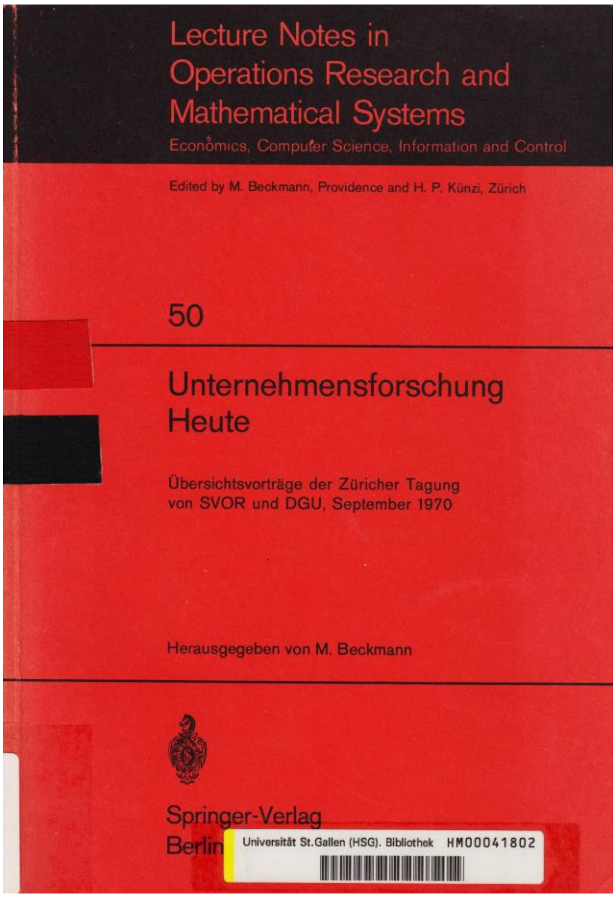


Figure 1: Lecture Notes, Volume 50, 1971

As the individual titles indicate, both Lecture Notes series united a colorful bouquet of diverse topics: e.g. OR procedures for operational applications, such as queue calculations. Then titles appeared on statistics, econometrics and economics. Together with Otto Opitz, Rudolf Henn published a textbook with a standard text on neoclassical consumption and production theory (OR series, vol. 25, 1970), which was used as accompanying material to the basic lectures at the TH Karlsruhe. But research reports were also published. Carl Christian von Weizsäcker, Professor of Economics at the University of Heidelberg, published a research report on Steady State Capital Theory (OR Series, Vol. 54, 1971). As volume 50 of the OR series, Martin Beckmann published the volume "Unternehmensforschung heute" in 1971, which contained six purely mathematical overview lectures at the joint conference of SVOR and DGU in Zurich in September 1970 (cf. figure 1):

- W. Dinkelbach: About a solution to the vector maximum problem,
- F. Fenschel: Recent developments in the field of queuing theory,
- D. Hochstädter: Recent developments in stochastic storage theory,
- P. Kall: Development trends in mathematical optimization,
- B. Korte: Integer programming,
- W. Uhlmann: Basic concepts of decision theory.

The fact that the editors of the Economics series combined the "Mathematical Systems" with "Economics" in the series title proved to be favourable for the marketing of mathematical OR methods and thus gave the "Mathematical Systems" a relevance in terms of content.

The international cooperation of national OR companies contributed to the formation of an international, self-referential system Operations Research and explains its explosive growth. As early as 1959, the US, English and French national OR society founded the International Federation of Operations Research Societies (IFORS).[90] The forerunner conference of IFORS on 2-6 September 1957 in Oxford (England) had 250 participants, among them two Polish participants as the only ones from the communist bloc.[91] The participants came mainly from Nato states and from India and Australia. In the lavishly edited conference report, all 250 participants are identified by name with a photograph in a three-page photo index and listed by country in the list of participants. According to the photo index, about 10 participants were female, including Dr. Anna Maria Restelli of the Centro per la Ricerca Operativa of the University of Bucconi in Milan, whose boss Francesco Brambilla, however, is listed as a OR–professor.[92] So, it is an open question whether a female OR–professor attended the conference.

Stafford Beer of United Steel, who later became famous as a management consultant, spoke at this conference - in the absence of a digital high-performance computer - on mechanical moulds for the simulation of production processes. Seven members of AKOR also took part. As chairman of AKOR, Hans Kregeloh, a graduate mathematician, spoke about the spread of OR methods in Germany, Austria and Switzerland. He also reported on the foundation of AKOR in 1957 in Darmstadt and the use of an analog computer for solving OR problems at his Institute for Practical Mathematics at the TH Darmstadt [93]

AKOR sent 16 members to the second conference of the IFORS in Aix-en-Provence from 5 to 9 September 1960. In 1960, the IFORS had already reached 10 members, all of whom - with the exception of India and Australia - came from the Western Alliance of NATO: the Netherlands, Norway, Sweden, Belgium, Australia, Canada, U.S. and Great Britain.[94] At the third IFORS conference in Oslo from 1 to 5 July 1963, two members of AKOR reported on the results of

---

[90] Rand, Graham: IFORS: the formative years, in: International Transactions in Operational Research, 7(2000), p. 101–107.
[91] Davies, Max (ed.): International Conference on Operational Research (Oxford), London 1957.
[92] Ibidem, p. 523.
[93] Ibidem, p. 494.
[94] Rand, Graham: IFORS, p. 106.

their work in practice.[95] For the young Federal Republic of Germany, these international contacts were extremely important in order to gain some reputation in post-war Europe. In 2006, the IFORS admitted Stafford Beer to the OR Hall of Fame.[96] John Krige described how, in the 1950s, the U.S., by exporting soft power to Europe, wanted to align the values of European scientists with the liberal values of the U.S. in order to build a bulwark against communism.[97] Instruments were an exchange of scientists, scientific conferences and summer schools. Whether the founding of IFORS was financially supported by the U.S. has not yet been investigated. Nevertheless, the pattern of IFORS falls within the soft power policy of the U.S.. It is obvious that Europe, impoverished by the Second World War, could not finance international conferences that required expensive trans-Atlantic tickets. Rand refers to the travel funds provided by UNESCO, UN or OEEC.[98]

In 1975 the Aachen OR professor Hans-Jürgen Zimmermann united eleven national OR societies of Western Europe (i.e. excluding countries from the Eastern Bloc) under the umbrella "EURO".[99] While IFORS organised its international meetings every three years, EURO offered its international conferences in the remaining two-year gaps, which were attended by up to 2000 participants, as reported on the EURO website. EURO has been publishing the European Journal of Operational Research since 1976, whose explosive growth can be measured by the fact that the 96th volume was published in 1996. These international cooperations formed a self-referential system. An OR researcher at a university in Germany was able to attend the DGOR conferences every year, give lectures there and publish them as papers in the proceedings. These steps enhanced the scientific reputation. Without the quality of the papers increasing once again, researchers were able to present the nationally presented papers unchanged on an international level, thus doubling their reputation and combining it with a varied trip abroad.

As an analysis of the DGOR proceedings revealed, the vast majority of contributions were model theoretically without an empirical part that would have presented collected data. The self-referential system Operations Research thus offered a platform for extensive model theoretical activities that shielded scholars from the need to collect empirical data. At the annual conference of the DGOR 1981 in Göttingen, Heiner Müller-Merbach, since 1972 Professor of Business Administration and OR at the TH Darmstadt, had already taken a stand

---

[95] Brusberg, Corporate Research, 1965, p. 242.
[96] Jonathan Rosenhead: IFORS'Operational Research Hall of Fame: Stafford Beer, in: Intl. Trans. in Op. Res. 13(2006), pp. 577–581.
[97] Krige, John: American Hegemony and the Postwar Reconstruction of Science in Europe, Cambridge (Mass) 2006.
[98] Rand, IFORS, 2000, p. 104.
[99] Euro – The Association of the European Operational Research Societies, Newsletter 2, Brüssel 1975. Zimmermann, Founding 1995.

against the hypothetical and nominal nature of many OR papers, which, for example, invoked a fictitious industrial enterprise with the words "An industrial enterprise has three machines..." to then continue the model-theoretical approach. He called for a stronger empirical orientation. However, his appeal had no effect and the congress machines of DGOR, EURO and TIMS continued undisturbed to gain reputation. The annual conference of GOR 2017 in Berlin was still attended by 900 people.[100]

The image that AKOR, DGU and DGOR drew of Operations Research in the specialist public led to an exaggerated expectation of business leaders in Germany in the 1960s. The University Seminar of Economics of the University of Bonn, which saw itself as a education institute for business executives, criticized these expectations in a publication in 1971: "These ideas are taken to extremes when the mathematical procedures are seen in connection with the still mystical role of the computer... A member of the board of a large energy company, for example, had the expectation that one only had to collect some data and pull some machine programs off the shelf in order to receive the optimal investment plan at the other end of the computer....“[101] In this respect, these expectations of business executives were exactly what the OR university researchers had pursued with their self-referential approach.

The history of the institutionalization of OR conveyed here shows the dual role of numerous chairs in the fields of OR and econometrics. These are the chairs of Drèze, Beckmann, Henn and Krelle. Also numerous conference organized panels both for econometrics and for OR. Beckmann and Künzi also offered a series of publications on both subject areas in their Lecture Notes. In 1979 Martin Beckmann together with Günter Menges and Reinhard Selten published the Handbuch der mathematischen Wirtschaftswissenschaften (Handbook of Mathematical Economics), which contained volumes on Operations Research and econometrics. In terms of scientific history, the dual role of OR and econometrics is remarkable because it is a coupling of two incompatible areas. Econometrics is macroeconomically oriented and uses empirical data on the national economy and its interdependencies, which it obtains from the Federal Statistical Office, as significant input for its mathematical models. Econometrics thus belongs to empirical economic research, which makes predictions and is therefore relevant for policy advice and in the economic departments of banks.[102] On the other hand, Operations Research is focused on operational processes and provides mathematical procedures independent of empirical data without making predictions.

---

[100] GOR was the successor organisation to DGOR. http://www.gor-ev.de/rueckblick-or-2017-in-berlin. (accessed on 30 May 2018).
[101] Hanssmann, 1971, p. 25.
[102] Nützenadel, economists, 2005, p. 92.

The ideas of Operations Research were also disseminated in the socialist GDR. There the term "Unternehmensforschung" was not used, but "operational research". The Grundlagenwerk by Werner Dück and Manfred Blieferich appeared in 1971 in a three-volume work in East Berlin, which can be seen as a remake of the book by Henn and Künzi.[103] Also in volume 1 there are, as with Henn and Künzi, only mathematical basics in analysis and linear algebra. Volume 2 deals with game theory.

5 The reluctant application of Operations Research in industry

In a clear difference to the flood of publications on theory-based OR topics, however, the use of OR methods in the industry remained low. Martin Beckmann simply reversed this relationship between theoretical supply and user demand when, in 1979, he claimed the opposite: "Mathematical processes are finding ever more applications in the economic and social spheres, especially where decision-making in complicated situations is at stake. Operations research in particular, which involves the application of mathematical models for economic decisions, has developed rapidly due to this need...".[104]

The low use of OR in the social spaces of industry was addressed by Merill Flood, president of TIMS and head of the mathematical department of RAND, when he concised in his presidential address in 1955 that OR, while generally recognised as important, was merely "in the air".[105] As a promoter of linear optimization, Dantzig emphasized that the first application of this method in the industry was the design of aviation gasoline in a petroleum refinery in 1951.[106] As Dantzig noted in his 1963 book, the industry's acceptance of using Linear Optimization in production planning was restrained.[107] In other publications he reports on the successful application in the oil industry.[108] Together with the head of an oil refinery, Bob Mellon, the University of Pittsburgh had carried out a linear programming project on behalf of the US Air Force for the most cost-effective blending of aviation gasoline. [109] The model contained 22 variables and was solved with the help of electro-mechanical desk calculators. The authors Charnes et al. did not mention the use of a digital IBM CPC machine or even a digital electronic computer. The motivation of the Air Force Treaty remains unclear. Was there a predominant

[103] Dück/Blieferich, Operations Research, 1971.
[104] Beckmann, Operations Research 1979, foreword.
[105] Flood, Objectives, 1956.
[106] Charnes/Cooper/Mellon, Blending, 1952.
[107] Dantzig, Programming, 1963, p. 28. The book was published under the copyright of RAND.
[108] Dantzig, Operations Research in the World, 1965. See also Steinecke for applications, 1973.
[109] Charnes/Cooper/Mellon, Blending, 1952.

shortage of aviation fuel? Or was the topic "aviation gasoline" a sufficient justification for an Air Force contract? These questions shed light on the Air Force's diffuse motivation in its R&D policy. In 1957, the linear programming approach in the oil industry was criticized by the RAND Corporation, of all people, as being too simplistic. The maximum profit of a refinery would depend on many other additional factors not included in the model. [110] These objections relate to the validity of linear programming approaches. Validity is a quality criterion of model construction cultivated by the applied statistics, which is otherwise ignored by the OR literature. Behavioral economist Herbert Simon's approach, published in 1959, of settling for bounded rationality in modeling puts the cost of information acquisition as a bound on model refinement. Simon's behavioral approach is a counter to the mathematical paradigm of operations research. [111]

The low success of OR methods is also related to the fact that US companies had already increasingly used scientific methods in management in the 1930s and 1940s and therefore the need for consulting was not pronounced. The consulting services for the introduction and improvement of punch card technology in business administration by the field organizations of IBM and Powers should be mentioned here.[112] In Germany, too, the performance mobilisation of the Nazi war economy led to a high level of scientific penetration of the production process, which initially did not trigger a need for OR consultants.[113]

The situation was different in Great Britain, where the management of companies showed great deficits. There, OR was successfully applied in public utilities and in basic industries. There was talk of the "Golden Age of OR" in the period from 1945 to 1970 and OR was seen as a means of modernising the industry. OR research groups were installed mainly at the association level, such as the OR Research Group of the British Iron and Steel Research Association, founded by Sir Charles Goodeve in 1950. [114] The fairytale rise of Stafford Beer, born in 1926, to become an internationally renowned management consultant also began in

---

[110] Goldstein, Scientific Aids, p. 37.

[111] Herbert Simon: Theories of decision making in economics and behavioural science. In: American Economic Review. Vol. 49, No. 3, 1959, p. 253–283. Simon schwankte zwischen dem verhaltenswissenschaftlichen Ansatz und mathematischen OR–Papern, siehe Erickson et al., How Reason, p. 207.

[112] Atsushi Akera, Calculating a Natural World - Scientists, Engineers, and Computing during the Rise of U.S. Cold War Research, MIT Press 2007.

[113] Kirby, Maurice und R. Capey: The Origins, p. 309. Flachowsky, Sören: Das Reichsamt für Wirtschaftsausbau als Forschungsbehörde im NS-System. Überlegungen zur neuen Staatlichkeit des Nationalsozialismus, in: Technikgeschichte, vol. 82 (2015), issue 3, pp. 185–224.

[114] Kirby, Maurice und R. Capey: The Origins and Diffusion of Operational Research in the UK, in: The Journal of the Operational Research Society, Vol. 49, 1998, No. 4, 307–326. Kirby, Maurice: Operational Research in War and Peace: The British Experience from the 1930s to 1970, London 2003.

the British steel industry. In the typical British career pattern of the gentleman manager, Beer had studied psychology and philosophy for only one year before he went into military service in India.[115] When he left the army in 1949 with the rank of Captain, he joined a subsidiary of United Steel in Sheffield as a management trainee and was able to successfully establish an OR group there, which he then expanded to include the entire United Steel Group. In his OR group he employed 70 people - probably the largest OR group in the world in a private company - and in 1956 he received the first large digital computer (Ferranti Pegasus) which could be used outside the field of scientific computing for management issues at United Steel. An important topic for him was the simulation of industrial production processes. His approach was similar to that of Jay Forrester to the simulation of industrial processes. At the IFORS OR Congress in Oxford in 1957, he presented a paper on mechanical processes for simulation, i.e. without using a computer.[116] Beer was strongly influenced by Norbert Wiener's widely distributed book "Cybernetics" (10th edition New York 1952).[117] He advocated an interdisciplinary and participatory approach and also became known for his publications, such as the book "Cybernetic and Management", which appeared in 1959, received a third, extended edition in 1967 and was translated into numerous languages, or the book "Decision and Control: the Meaning of Operational Research and Management Cybernetics", which appeared in London in its fifth edition in 1967.

In contrast to Great Britain, however, there were obstacles in the U.S. and West Germany to the broad application of Operations Research in the social spaces of companies, also to the extent that the models required empirical data in order to be able to calculate optimal solutions. However, the data were only to be collected in the enterprises. In OR publications, this data problem is mostly played down with formulaic statements. In his basic paper "Procedures of Operations Research and their Applications in Industry" in volume 1 of his journal "Operations Research Verfahren" Rudolf Henn writes: "In many operational processes it happens that one has a probability distribution in each time period for the variables." He doesn't say how to determine these probability distributions. Other professors could not answer these questions either. Rather, a division of labour between universities and "practitioners" in industrial companies developed. As the topics of the DFG small projects on OR by Professor Horst Albach shown above display, these are exclusively model theoretical without empirical reference. Albach also led the University Business Seminar at the University of Bonn, which saw itself as a further education institute for business executives. For this seminar he had the management consultant Friedrich Hanssmann write a paper on Operations

[115] The Bio–Data of Beer from Jonathan Rosenhead: IFORS'Operational Research Hall of Fame: Stafford Beer, in: Intl. Trans. in Op. Res. 13(2006), pp. 577–581. For the gentleman manager in Great Britain see Jon Agar: The government machine: a revolutionary history of the computer, MIT Press 2003

[116] Stafford Beer: The Mechanical Simulation of Stochastic Flow, in: Davies, Max (ed.): International Conference on Operational Research (Oxford), London 1957.

[117] For the history of Cybernetics see Thomas Rid: Rise of the Machines. A Cybernetic History, New York 2016.

Research in which Hanssmann vividly described the difficulties of data collection in the company.[118] Albach wrote the foreword and thanked Hanssmann for his hard work. Albach, whose DFG projects and his 1967 paper can be regarded as a promoter of Operations Research,[119] had thus shifted the responsibility for empirical research to a practitioner. Albach also hinted at the reluctant application of OR methods in industry.[120] Nievergelt and others talk in their practical studies on Operations Research about the "high sacrifices" that their company had to make when introducing OR.[121]

In order to obtain data, the mathematically oriented OR researchers at the universities had to go into the social spaces of companies, for which, however, they did not have a social science education. From the perspective of a company's management, it is well known that collecting data about the individual operational processes within the company is both laborious and expensive. There is also resistance from the lower management to have their own decision-making area examined.[122] Management therefore balances the quality of the data against the cost of collection and tends towards simple rules. But OR consultants had to jump over the data collection barrier to gain high quality data that they could incorporate into their refined OR models. Because of these difficulties, the scale of Operations Research applications in the companies ultimately remained low. For example, Lewis Bodin wondered how low the level of vehicle route planning applications, such as milk collection from farms in the countryside or school bus planning in the suburbs, were in the 1990s, even though the scientific community had been researching route planning for 20 years.[123]

If one considers the promise of cost reduction through the use of operational research methods, the OR consultants were only able to reduce a small proportion of the costs with their models, since many industrial processes carry high fixed costs, so that a reduction of, for example, 5 percent of the variable costs did not seem particularly convincing. In addition, many processes showed cost curves that did not show a sharp minimum, so that deviations from the minimum costs were only of minor importance and rough estimation methods could be applied. In literature there is no known cost curve with a sharp cost minimum, such as a crack in a rock, which would justify an elaborate search for the cost minimum.

---

[118] Hanssmann, Corporate Research, 1971, p. 25.
[119] Albach, Corporate Research, 1967.
[120] Ibidem, p. 254.
[121] Nievergelt, E, O. Müller, F. Schlaepfer: Practical studies on corporate research, foreword.
[122] Kaplan/Cooper, Cost 1998.
[123] Bodin, Years, 1990.

In their OR book of 1957, Churchman et al. showed in detail how data collection methods, such as cost curves in steel mills or queues at toll stations on the New York city highway, were carried out and spread warnings that OR researchers should not concentrate on methods but rather collect data in the company.[124] They should also become familiar with the social relations in the company from which they received the consultancy mandate.

However, the OR researchers did not turn to empirical projects in the social spaces of companies, but established themselves successfully in the social spaces of the economic science faculties of the universities. There they advanced the development of mathematical optimization methods and transformed their textbooks on Operations Research into pure method bibles. In volume 1, Henn and Künzi's two-volume work on Operations Research did not deal at all with Operations Research but only with mathematics: set theory, linear algebra, probability theory and statistics. Volume 2 also contained a chapter on game theory. Since Operations Research did not focus on economic relations within the company, empirically oriented research was largely lacking. The strong emphasis on mathematical methods has been rejected by business leaders since the 1950s. The OR specialists were accused of using incomprehensible "technical jargon", as Walter Trux, head of the mechanical engineering group Fichtel und Sachs, put it in his opening speech at the 1980 annual conference of the German Society for Operations Research in Essen.[125]

6 The rise of business informatics as a barrier to operations research

If the dissemination of OR is historicized, after a phase of successful institutionalization at the universities until 1970 there was stagnation and decline after 1980, which is due to the rise of the competing fields of business informatics and logistics.[126] Since the end of the 1980s, chairs for Operations Research have increasingly been converted into the fields of business informatics and logistics. As a specialist representative of OR professors at German universities within the Association of Business Economists, the Scientific Commission Operations Research increasingly lost members with the Denomination Operations Research. In 2019 only two of the 100 professors (chairs only within Germany, without Emiriti) of the Scientific Commission Operations Research possessed the denomination Operations Research,

---

[124] Churchman et al., Introduction, 1957, chapter 21.
[125] Rider, Operations, 1992, p. 231. Trux, Deployment, 1981, p. 21.
[126] Bradtke, Operations Research, 2003, speaks of a crisis of the OR at the end of the 1970s, p. 3. Rudolf Henn stopped publishing his journal Operations Research Verfahren in 1979.

while the others possessed the denomination Business Informatics or Logistics.[127] A crisis of OR was also perceived in Great Britain.[128]

Apart from these academic upheavals, the use of Operations Research in corporate social spaces has also been hampered by the rise of database systems for production control. This business management control of enterprises by computers can be historized as follows. The capacity of companies to modernise their own organisation was absorbed between 1960 and 2000 by the installation of ever newer and more powerful generations of computers for business management of production and could hardly pay attention to the advice of OR consultants. In the production industry the application of the relational database models preferred by business informatics for the control of the material flow in the production of the manufacturing industry stood in the center, while still in the 1960s IBM had favored hierarchical database models in vain. The relational database models became possible in the 1960s, when the transition from Turing-like linear storage on tape to random access to magnetic disks took place and file systems became possible for the first time ever. The example of Fichtel & Sachs AG in Schweinfurt illustrates the growth in disk capacity. In this company, the disk capacity grew from 2.8 MB in 1975 to 15 MB in 1980.[129]

Dieter Pressmer, Professor of Operations Research at the University of Hamburg (see above), initiated a funding programme for the University's Information Systems department at the Federal Ministry of Education and Science in the 1980s and founded the Institute for Information Systems at the University of Hamburg in 1995.[130] The programs developed by Business Informatics for production control in the manufacturing industry (also known as PPS) date back to the simple bill of materials processors of the 1960s. As the first programs to efficiently utilize high-speed digital computers, Job Shop Scheduling programs were developed in the early 1950s that determined an optimal sequence of application programs (jobs) that were read into the computer as punch cards in batch to minimize the total waiting time of the valuable processor. These job scheduling programs were later integrated into PPS. PPS has been extended to include the management of additional operational functions such as sales, suppliers, finance, human resources and building planning, including various locations at home

---

[127] Message from the Chairman of WK Operations Research, Professor Achim Koberstein, University Frankfurt/Oder.
[128] Fildes, R. and J. Ranyard: The foundation, development and current practice of OR: An editorial introduction and overview, in: Journal of Operational Research, vol. 49, 1998, 304–306.
[129] Opening lecture at the ninth annual conference of the German Society for Operations Research in Essen in 1980 by Walter Trux. Trux, Mission, 1981, p. 22.
[130] The Pressmer obituary on the website www.bwl.uni-hamburg.de/iwi/ueber-das-Institut/pressmer.html, accessed on 15 March 2019.

and abroad and referred to as Enterprise Resource Planning (ERP).[131] This meant that the entire company organization was mapped in this database program, but this did not always go smoothly. During the program installation in the companies conflicts arose between the rigidity of the intended software and the living organization of the companies.[132]

In the manufacturing industry, database models split the structures of machines, materials and bills of materials into thousands of tables in atomized normal forms, resulting in long runtimes on the computer to create production plans for the following day due to numerous hard disk accesses. The computers were running all night. This disadvantage could only be remedied when semiconductor-based main memories in the gigabyte range became technologically possible from the year 2000 onwards and thus the slow hard disk accesses to the atomized tables could be shifted to the fast main memory. The SAP software group sold this new ERP software under the HANA brand. In the 1990s, SAP added an optimization tool based on linear programming called "Advanced Planner and Optimizer" to its R3 production planning product.[133] There is no empirical knowledge about the use of this tool. Whether it was useful for production companies or just a marketing campaign by SAP cannot be decided.

7 The initially problematic use of the large computer in mass data processing

In this section, the problems of mass data processing with large computers in the social spaces of companies in the 1950s due to the small size of the main memory are to be pointed out, in order to then lead over to the topic of OR as management science.

I follow Timo Leimbach here, who in his study on the software industry distinguishes between two types of use of computers for administrative purposes in companies. On the one hand the computer as an automation of simple employee work and on the other hand as a tool that provides information to enable the manager to make decisions.[134] In the 1950s, the large computer was introduced into companies to automate administrative processes such as sales statistics, payroll accounting and warehouse management. Many of these areas had already been partially automated by the use of punch card machines, and the computer was able to

---

[131] Crank, Enterprise, 2011. Fleischhack, World, 2016. She reports on applications of job shop scheduling programs in municipal data centers as late as the 1970s, p. 58.
[132] For an example of the SAP R/3 implementation conflicts at M.I.T. see Williams, Solid, 2000, p. 641-668.
[133] Bartsch, SAP APO, 2000.
[134] Leimbach, History, 2010.

continue these approaches of the punch card departments in the companies, especially since the input and output of data still took place via punch cards.[135] John von Neumann had given the digital large computer a special architecture. He combined a fast arithmetic unit with a fast main memory. This architecture made it possible to integrate differential equations, in particular, by moving millions of iteration steps of small amounts of data back and forth between the main memory and the arithmetic unit in a very short time. For computer manufacturers, the large digital computer in business administration was not a particularly large sales market in the 1950s. The number of installations remained low. In fact, a different architecture prevailed which von Neumann had not taken into account. A fast arithmetic unit was combined with a slow main memory realized by a magnetic drum. Among the up to 70 types of digital computers with magnetic drums that appeared on the market in the U.S. in the 1950s,[136] the IBM 650 became the successful model of this architecture.

A large computer such as the IBM 701 or the Univac 1103 may have been successful in scientific calculations such as the integration of differential equations, but its application in administrative data processing looked less favorable. This application was accompanied by a great rationalization rhetoric of efficiency, speed and cost savings. However, as Thomas Haigh pointed out in his study on the introduction of digital computers for administrative data processing in the 1950s, this path was extremely laborious because large computers only had tiny main memories and the processing of mass data had to be split into numerous separate runs. The speed advantage of the large computer was thus lost.[137] However, the classic tabulating machines did not have this main memory restriction.

In administrative data processing, sorted data stocks were particularly important. Sales data, personnel data, customer data, material data and supplier data were given numbering systems with which certain data records could be quickly found in a sorted inventory; the magnetic tape only had to be prewound until the data record number appeared. However, the data always had to be re-sorted as soon as changes occurred. Unlike punched cards, however, the linear magnetic tapes became cages for the mass data. Sorting mass data stored in magnetic tapes on large computer systems proved to be a major bottleneck, as the tapes with mass data had to be split into numerous separate runs due to the small main memory, while sorting on punch card machines was possible without any problems. Paul Ceruzzi estimated that large computer systems spent 25% of their time sorting. In an advertisement, the

[135] Vahrenkamp, Informationsexplosion, 2017, pp. 209-242. Extended version at http://www.vahrenkamp.org/files/Punch_Cards_Vahrenkamp_WP1_2017.
[136] Weik, Survey, 1955.
[137] Haigh, Tabulator, 2001.

Electronic Data Division of RCA even speaks of 40% for sorting.[138] The slow main memory of the IBM 650 and the slow mass memory with magnetic disks (600 milliseconds average access time) of the IBM 1401 did not play a role in the cumbersome sorting processes.[139] In computer science, sorting algorithms became an important field of research; Donald Knuth of Stanford University published a sorting bible in 1973 that was overflowing with over 700 pages.[140]

While the medium-sized IBM machine 650 did not yet have its own printing unit, but had to be connected to a tabulating machine, the machine 1401 together with the high-speed printer 1403 in 1959 brought IBM a breakthrough in administrative data processing with computers. The 1000 lines per minute high-speed printer was able to print an image of the company's data on huge piles of paper that were transported to the offices on small trolleys.[141]

The success of the 1401 was due in part to the fact that many programs from the old IBM tabulating machines could be transferred to this machine with translation programs – as was already the case with the IBM 650. IBM further developed the tabulating machine-oriented approaches in administrative data processing when it introduced the S/360 large computer in the 1960s. In this machine there was a status that emulated the successful machine 1401. This allowed the old programs of the 1401 to continue to be used and convinced customers to switch to the 360 machine. The great success of IBM's punch-card oriented software product "Report Program Generator" (RPG), which lasted until the 1980s, with the sum[142] of a turnover list or similar lists being drawn over various criteria and printed out as reports on paper, on the IBM S/360 demonstrates this policy of continuing the old tabulating machine approaches of administrative data processing, which certainly also explains IBM's market success in part.[143] In a way, it seems absurd today if the old tabulating machine programs ran in the slow 1401 mode on the high-performance S/360 machine, but this indicates the great importance of report lists for company management.[144] As long as mass data was stored on tapes as the primary storage medium and not yet on random access disk drives, the high speed of the

---

[138] The advertisement of RCA Electronic Division can be found in Datamation, Vol. 6, 1960, p. 7. Ceruzzi, History, 2000, p. 89. Vahrenkamp, Informationsexplosion, 2017, shows the importance of sorting processes when punch cards are used.

[139] Baer, 1400 Series, 1976, p. 629s.

[140] Knuth, Computer Programming, 1973.

[141] Haigh, Tabulator, 2001, p. 86. Ceruzzi, History, 2000 p. 73s.

[142] Other statistical functions could also be programmed, such as mean, minimum and maximum of the values in question. The function maximum was important for utilities. In industry electric power was rated according to the daily maximum use.

[143] Campbell-Kelly/Aspray, Computers, 1996, p. 133. On RPG see Rottmann, IBM/360, 1966. Heger, 100 years, 1990, p. 140-144. On the use of hard disk drives for seat reservation for 1000 flights per day of the US airline United Airlines on the IBM machine RAMAC already in 1959 see Thompson, RAMAC, 1959. I owe this source to Dr. Daniela Zetti of ETH Zurich.

[144] Ceruzzi, History, pp. 149-151.

S/360 machine could not really be exploited anyway, so the slow 1401 mode did not carry much weight.

8 Management Science and Operations Research

In the automation debate of the 1950s, the second aspect of the use of computers was also strongly emphasized: to provide management with data to support them in decision-making situations, as the report lists already did. The explanations went so far as to formulate also the goal of automating or at least partially automating decisions of the management with the digital computer.[145] A recourse to the methods of Operations Research gave this field the aura to provide the necessary methods for the automation of management decisions. As early as 1955 – when hardly any large digital computers were installed in administrative data processing – Herbert Simon and Russel Ackhoff held a conference at Harvard to support management decisions using computers and OR methods.[146] In 1960, Simon published the book "The New Science of Management Decision", which was influential in the automation debate. In this book Simon enumerates the two possibilities of computer use, the automation of simple employee work and the support of management. Typical of the uncritical approach in the automation debate, he saw Frederick Taylor and Taylorism as precursors of Operations Research.[147] Simon could not provide concrete approaches to how management decisions should be supported, but he only presented keywords by enumerating the various methods of operations research, such as game theory, dynamic programming, linear optimization and simulation.[148] Looking at the stony path outlined above that computer applications had to take to automate simple employee work in the 1950s, Simon's remarks seem fabulous. At that time it was not possible to simply use the computer as a working tool, for example by approaching a computer and entering a query about turnover, stock or financial resources on the screen using the keyboard. Rather, the computers had only input consoles with switches and light bulbs, but without a screen. After all, punch cards for programs and data had to be produced, compiled and read into the computer.[149] How sophisticated programs for the analysis of large amounts of data should be executed in the tiny main memory, and thus even managers could be supported, remains a matter of fantasy.

---

[145] Simon, Management, 1960, p. 14. The automation of management decisions was also discussed in the Soviet Union, see Gerovitch, Cybernetics, 2002, p. 266.
[146] Ackhoff/Simon, Proceedings, 1955, where Ackhoff recommended the use of Operations Research for management.
[147] For the automation debate see Vahrenkamp, Botschaften, 1988. For the Taylorism debate see Vahrenkamp, 1977, updated as Working Paper at: http://www.vahrenkamp.org/files/WP20_2018.pdf .
[148] Simon, Management, 1960, pp. 14-16.
[149] For the process of compiling with the Fortran language on the IBM 650, see the Columbia University field report at http://www.columbia.edu/cu/computinghistory/650.html. (Retrieved on 30 May 2018).

To use Operations Research, of all things, to support management was of little use, since the promoters had not taken into account the merely low empirical orientation of Operations Research. Thus, Operations Research could not provide the empirical methods to support management. The representatives of Operations Research were also the wrong addressees of Simon's automation thesis in so far as they had kept their field of expertise largely free of computer applications. In the textbooks on Operations Research, no reference is made to the computer. In the basic work by Henn and Künzi from 1966, the "electronic calculator" is mentioned only once in old-fashioned terminology.[150] As in the textbooks, the same picture can be seen in research. In the proceedings of the annual conferences of the German Society for Operations Research and Operations Research, lectures on computer applications only occur occasionally: At the 1971 meeting not at all, at the 1972 meeting only two papers among 30 papers.[151] As one of the few OR scientists, the graduate mathematician Ulrich Derigs, employed at the "Seminar for Industry" of the University of Cologne, published software for solving OR algorithms in 1980 together with Rainer Burkhard, Professor of Mathematics at the Mathematical Institute of the University of Cologne.[152]

When computers became more powerful in the 1960s and screen terminals, timeshare systems, file systems on hard disk drives and database systems based on them could be set up, the idea arose to give upper management easy access to the information that was already available in the databases of the operative mass data processing systems. This led to a debate on management information systems (MIS) with a rapidly growing number of publications, with the focus on information provision, but Operations Research only playing a secondary role.[153] In MIS, the manager was designed as a user who could start terminal queries in the database. Setting up an MIS was considered expensive and its usefulness more difficult to prove than in mass data processing. It remained controversial whether the MIS promoters had promised too much. Some authors even saw a failure in MIS.[154] In the age of MIS Stafford Beer's cybernetic experiment in Chile took place[155]

---

[150] Henn/Künzi, Corporate Research, 1966, Volume 2, p. 171.See also the computer free textbook of Nickel, Stefan, Oliver Stein, Karl–Heinz Waldmann: Operations Research, Berlin 2011.
[151] Physica Verlag Würzburg 1972 and 1973, respectively.
[152] Burkard/Derigs, Assignment, 1980.
[153] Alavi/Carlson, Review, 1992, pp. 45-62.
[154] Teichroew, Management, 1976, pp. 845-847.
[155] Eden Medina: Cybernetic Revolutionaries, MIT Press 2011.

9 The Computer and Simulations in Operations Research

In the literature, the topic of simulation covers a wide area. This section is limited to discrete Monte Carlo simulations, without going into simulations that solve systems of differential equations with computer programs, as in meteorology, astrophysics and industrial dynamics by Jay Forrester.[156]

In Operations Research, the discrete simulation of production systems or traffic systems was also a topic. They were used as software programs on digital computers when no closed solutions with mathematical formulas could be derived and parts of the system depended on random variables with certain distribution functions. They were also used when experiments with real systems were too expensive or too dangerous, such as chain reactions in a critical mass of uranium atoms.

The debate on Monte Carlo simulation takes up the complex of questions 7 on political knowledge cultures of the workshop Algorithmic Knowledge Cultures and places them in the context of Cold War Science in Los Alamos. John von Neumann was the first scientist ever to use simulation supported by random numbers. He wanted to get a heuristic impression of the scattering of neutrons during chain reactions in atomic bombs and "optimize" these bombs according to certain goals. His wife, Clara von Neumann, and Nicholas Metropolis programmed the ENIAC computer and together calculated neutron scattering in 1948.[157] Both were equipped with numerous punched cards containing random numbers. Klara von Neumann and John von Neumann both came from upper middle-class homes in Budapest and had personal experiences of visiting the gambling casino in Monte Carlo, Monaco.[158] Based on an idea by Stan Ulam, both Stan Ulam and John von Neumann had invented the use of randomised methods in 1946 in Los Alamos and gave the method the name "Monte Carlo method". This term fascinated mathematicians and scientists immediately, because Monte Carlo was probably associated worldwide with gambling. The RAND Corporation of the US Air Force jumped on this trend. Although she did not have a digital computer in 1949 and had no experience with simulation, she organized the first scientific conference on the Monte Carlo method in Los Angeles at UCLA University, which was later followed by others.[159] Remarkably,

[156] For simulation in meteorology, see Gramelsberger, Computerexperimente, 2010, p. 209. Forrester, Industrial, 1961. This book later provided the methodological model for the world model of the Club of Rome.
[157] On the ENIAC computer and the programming of Metropolis and Clara von Neumann, see Haigh/Priestley/Rope, ENIAC, 2016.
[158] For a biography of John von Neumann see Bhattacharya 2022.
[159] Monte–Carlo–Method: Proceedings of a Symposium held June 29, 30, and July, 1, 1949, in Los Angeles, US Government Printing Office, Washington D.C. 1951 (volume 12 of National Bureau of Standards: Applied Mathematics Series). Dyson, Turing's, 2012, describes in Chapter 12 the calculations of Klara von Neumann and

the contributions of this symposium make it clear that no digital computer is needed to generate random numbers. Instead, RAND generated their random numbers with a kind of fast spinning roulette table and published tables of random numbers that other scientists could use. Also, the evaluation of simulation experiments using the Monte Carlo method did not necessarily have to be done on a high-speed digital computer. Most of the authors report on the use of standard IBM punching equipment such as the IBM 602, 603 and 604 punching computers, and only one article deals with the use of ENIAC, the only high-speed digital computer available at the time.

Operations Research also adopted the Monte Carlo method and gave itself a mysterious coat of paint. However, in chapter four the authors Henn and Künzi brought almost exclusively trivial applications to the Monte Carlo method of their book (volume 1), such as the erratic "way of a drunken man" (random walk), the needle experiment of Buffon from 1733 and the turnover of a newspaper salesman. With these examples, they were unable to convince business leaders of the benefits of operations research, demonstrating that they had no intention of doing so, but were merely targeting the academic arena to present material for OR courses. With the success of Monte Carlo methods, the need for random numbers increased greatly to allow simulations to be repeated with a different set of random numbers, thus ensuring the replicability of simulation experiments. Textbooks published tables with equally distributed random numbers. A RAND Corporation publication with random numbers became a bestseller in the RAND book program.[160] In theoretical computer science, a separate branch of research grew up to develop software for the generation of equally distributed random numbers.[161] From the 1960s, Hans Künzi reported on applications of simulations at his Zurich Chair of Operations Research in cooperation with the Swiss Military. Air battles were simulated on the computer in order to determine a cost-minimal procurement of a fighter plane of different types. He also reported on simulations of inner-city individual traffic in order to optimize traffic light circuits.[162] OR experts in the communist German Democratic Republic also used the term Monte Carlo, but without referring to the casino.[163]

Nicholas Metropolis. Dyson's book is based on research in the Princeton University archives. Haigh/Priestley/Rope, ENIAC, 2016, Chapters 8 and 9 provide a detailed description of ENIAC programming. It is not known whether von Neumann achieved his goal of "optimizing" the atomic bomb with the Monte Carlo simulation. Monte Carlo Method, 1951. Galison, Computer, 2011, p. 125.

[160] 50 Years Project Air Force, 1996, p. 50.

[161] Donald E. Knuth: The Art of Computer Programming, vol. 2, chapter 3, Boston 1981 (second edition). Churchman et al., Operations Research, 1957, give on page 173 a table of random numbers they obtained from RAND Corporation. Henn and Künzi, Unternehmensforschung, 1966, give a table of random numbers on page 129s of volume 1. A history of producing a sequence of random numbers is given by Thomas G. Newman and Patrick L. Odell: The Generation of Random Variates, London 1971, pp. 2–5 and bibliography.

[162] Künzi, Corporate Research, 1972, p. 9s.

[163] Dück et al., Operational Research, 1971, Volume 2, pp. 383-387. Schubert, Efficiency, 1965.

While the Monte Carlo method had been developed in physics, it also radiated to engineering and operations research to try to solve complicated equations, which were created in a non-probabilistic environment and could not be solved by numerical methods, with randomly generated data sets. In this way, numerical mathematics achieved an experimental character, as is always emphasized in the literature on the Monte Carlo method. One can also include the Monte Carlo method in the use of random numbers and the concept of probability in the management of telegraph lines in the 1930s. Statistical considerations in the transmission of texts in telegraph lines were quite common. The letter E, which occurs most frequently in the English language, is designated in Morse code by only one dot. This coding is more economical than assigning a sequence of dots and dashes to the letter E. In cryptography, there were tables that indicated the probabilities that a certain letter would be followed by another in English texts (transition probabilities). As can be seen from Claude Shannon's 1948 information theory paper, the use of random numbers was quite common in science.[164] Claude Shannon gives an example of the random generation of pseudo English text using random numbers taken from a table in a book publication - not generated by a computer - from 1939. He also refers to Statistical Mechanics, in which discrete processes are simulated using Markov processes, which can also be applied to modelling the transmission of text in telegraph lines to save transmission capacity when transition probabilities from one letter to the following letter are taken into account.

The Monte Carlo approach was ideal for operations research because no computers had to be used for these experiments, but published tables of random numbers could be used. In fact, computers were only available in the OR community in the 1970s. At the same time, the reference to published random numbers shielded from the necessity of having to collect one's own empirical data. Operations Research was able to consolidate its position as desk research. Churchman et al. published in their OR textbook an example of how to determine a minimum-cost fleet of vans for delivering parcels to a department store using the Monte Carlo method on the desk. In their example the abstraction becomes clear. In the absence of empirical data, a normal distribution of the number of parcels arriving daily is assumed with a mean value of 1000 and a standard deviation of 100. Only five values from a table of a (0.1) normal distribution published in her book were taken, multiplied by 100, and the mean value 1000 added. With these elementary operations, the authors had random data for a calculation of the daily amount of packages. The authors were self-critical in their approach to abstraction, noting that the example of package delivery was "deliberately oversimplified".[165] In the same way, Henn and Künzi apply the Monte Carlo method to the maintenance of a machine park of "high-pressure injection pumps".[166] The reference to high-pressure injection pumps of all

[164] Claude Shannon: A mathematical theory of communication, in: The Bell System Technical Journal (Volume: 27 , Issue: 3 , July 1948), pp. 379 – 423, hier p. 389.
[165] Churchman et al., Introduction, p. 411.
[166] Henn/Künzi, Unternehmensforschung, Band 1, p. 135.

things suggests industrial applications of the OR. The examples of applications of the Monte Carlo method published by Churchman et al. in 1957 were widely used in the literature. For example, Henn and Künzi adopted the example of the path of a drunk man (random walk) without citing the source.[167] The Polish author Wieslaw Sadowski took over the example of delivery vehicles with reference in his OR textbook, which was published in German in East Berlin in 1963.[168]

The historization of simulation can also take up question for the visualization of the workshop Algorithmic Knowledge Cultures. While in the 1980s the simulation languages SIMAN and ARENA, mainly used by mechanical engineers for the simulation of production systems in batch mode, were still in use, software packages with graphical user interfaces came onto the market in the 1990s. Like a construction kit, it was possible to put together working machines, waiting rooms and material handling systems, visualise them on screens and identify bottlenecks in the material flow. The individual elements were provided with randomised arrival and departure times whose distribution could be chosen (equal distribution, normal distribution and Poisson distribution). Critical to the application of this software was to obtain empirical data on the behavior of individual elements. Characteristic data of the working machines of the mechanical engineering manufacturers and the experiences of production engineers were used.[169] While practical applications of simulation software for the layout of production systems have no known failures in the literature, it should be noted in theoretical terms that the results of layout simulations only provide mean values, but that large deviations can occur in the realization of random variables.

As the computing power of computers rose sharply, randomized procedures from Operations Research were able to test millions of alternatives in a very short time. Huge search areas could be scanned with realizations of random variables for favorable solutions.[170] In the 1990s, for example, numerous deterministic OR procedures were converted into randomised procedures. The use of evenly distributed random variables, which almost every programming language had implemented with a random generator, was now taken for granted, without even bombastically speaking of Monte Carlo. As a new research branch of Operations Research, genetic algorithms and simulated annealing were investigated.[171] The latter simulates the cooling behaviour of crystals in order to jump out of local minima and obtain better solutions. The former imitates evolution in nature. Values of variables were modeled as

[167] A.a.O., p. 133. Bei Churchman et al., Introduction, ist das Beispiel des betrunkenen Mannes auf p. 184 zu finden.
[168] Wieslaw Sadowski: Theorie und Methoden der Optimierungsrechnung in der Wirtschaft, Berlin 1963, p. 204.
[169] Eley, Simulation, 2012. Wenzel et al., Simulation, 2008. Herbert Simon pointed out as early as 1960 that simulation studies have a need for empirical data that is difficult to satisfy, see New Science, p. 19.
[170] For the one-dimensional cutting problem see Vahrenkamp, Random, 1996.
[171] Michalewicz, Algorithms, 1996, pp. 250-252.

binary 1-0 strings. With the mutation, individual positions in the string were changed randomly. With recombination, parts of two strings were randomly exchanged. The selection process selected the most promising randomized solutions. Genetic algorithms and simulated annealing were ideal fields for OR, as they gave new impetus to the method orientation of OR and finally connected the OR with the computer.

10 OR-Algorithms in Transport Networks

For the modeling of global supply chains of sea and air freight[172] as well as for the supply of households on the last mile, Operations Research has developed different methods. In addition to the algorithms for location selection in networks (median and center problems), four different approaches can be distinguished in transportation networks: the shortest path problem, the traveling salesman problem, the route planning problem, and the transportation model. [173] These algorithms are quite different and have little to do with each other. Only the route planning problem can implicitly build on the Travelling Salesman Problem. While OR provided the models, empirical research on transportation was the subject of transportation science, but not Operations Research.

The transportation model is presented in detail in Section 11. It looks for a cost-minimal schedule of deliveries from suppliers to demanders and is relatively easy to program in a spreadsheet. One first seeks a starting solution that includes some total cost of transport and then improves this starting solution incrementally until a cost-minimal solution is found. The criterion for optimality is easy to test. Or one is satisfied with a heuristic solution (Vogel's approximation method[174]).

The shortest path method searches for the shortest path from A to B in a network. It was developed by the Dutch computer scientist Edsger Dijkstra in 1959 and is a very simple and a very fast algorithm that can be programmed with a few lines of code. One can instantaneously determine the shortest path through millions of nodes, which is now a common cultural technique in electronic cartography.

---

[172] Richard Vahrenkamp: Globale Luftfrachtnetzwerke – Laufzeiten und Struktur, erweiterte Neuauflage, Igel Verlag, Hamburg 2014.

[173] Dirk Mattfeld und Richard Vahrenkamp: Logistiknetzwerke – Modelle für Standortwahl und Tourenplanung, 2. Auflage, Gabler Verlag, Wiesbaden 2014.

[174] Dürr et al., Operations Research, 1983, p. 105.

The Travelling Salesman Problem (TSP) searches for a closed round trip through all given nodes with the smallest sum of travelled distances among all alternative routes and is described in detail in section 11. A distinction is made between heuristic solutions, which are relatively easy to program and provide tours that can be about 3% (in tour length) above the optimal (shortest) tour, and the complex proof of a solution that is actually the shortest among all solutions of the TSP (optimal solution, exact solution). If one follows Simon's approach of bounded rationality with respect to data and computational performance, this approach is more in favor of heuristics for solving the TSP, especially since traffic data have a large range of uncertainty. [175]

In the route planning problem, one plans how in a city a truck delivers to different stores from a wholesale base. As a restriction, consider that the delivery vehicles are not large medium-duty 18-ton trucks or even heavy 40-ton trucks, but small maneuverable 7.5-ton or 12-ton trucks that can maneuver well in the city center and drive into narrow yard entrances. However, this smaller truck type means that the truck bed is so small that only orders for 5 - 10 stores can be transported, and thus only 5 - 10 stores need to be hit per tour. (The same is the case with delivery tours of general cargo forwarding companies). Because of the small dimension range of the TSP, which can be seen here, it can be solved very well heuristically with simple methods, if the delivery area is projected onto the road network of the city. Here, there are not many different ways to map out a tour due to the nature of the road network. So, one can use simple heuristic methods to compose delivery tours of 5 - 10 stores in the city area. Therefore, the exaggerated claims about the exact solution of large TSP are merely dreams of mathematicians who expand the problem to millions of cities worldwide, but have no application in logistic reality. [176]

In order to determine individual tours, it was necessary to define in advance the individual delivery areas in which the individual tours were to be optimized. There was no mathematical procedure for this decomposition until the publication of the British researchers G. Clark and J. Wright in 1964, where they were able to determine the delivery areas and at the same time optimized tours with the heuristic known as the Savings Procedure. [177] The approach of Clark and Wright is interesting in that it starts from an unusual initial solution, namely the one that is the worst of all solutions: Each store is served by a truck in a shuttle route from the depot, without including service to other stores. In an iterative process, shuttle tours are combined step by step that promise the greatest savings in travel distance back to the depot.

---

[175] Zur Kritik von Herbert Simon am Travelling Salesman Problem siehe Erickson et al., How Reason, p. 76.
[176] http://www.math.uwaterloo.ca/tsp/world/index.html. (Zugriff am 15. März 2020).
[177] Clarke, G. und Wright, J. W.: Scheduling of Vehicles from a Central Depot to a Number of Delivery Points, in: Operations Research 12 (1964), Heft 4, p. 568–581.

The use of tour planning software was slow to catch on. In 1990, Lewis Bodin was surprised about the low degree of application of this software, although the scientific community had already been researching tour planning for 20 years. [178] It was not until the 1980s that the main memories of the digital computers available in companies in the FRG were large enough, at around 300 kilobytes, to be able to use route planning software, such as the TRAFFIC package from Siemens. Especially in the distribution organizations of the well-funded companies in the beverage industry and milk processing, this software was used to supply restaurants and retail stores in cities. In FRG, problems with abstraction arose in route planning. The stores served by the delivery vehicles wanted to be served by the same driver each time in the recurring tours - a request that the route planning software did not take into account. There were also problems with including stores with different delivery rhythms in a common tour. [179] In the tour planning packages, the actual tour planning was significantly expanded into a truck fleet management system that included accounting for tours, vehicle costs and personnel deployment. However, high licensing costs by the software manufacturers hindered widespread use until the 1990s. [180] The cautious business strategy of the software houses was essentially based on equity rather than venture capital, which was not able to capture markets through low prices until 2000 with high initial losses.

11 The artificial content of Cold War Operations Research

The following section discusses the Transport Model, the Travelling Salesman Problem, and the Diet Problem and highlights their artificial content from Cold War Operations Research. But also other OR questions have this artificial content and were not used in business, so they remained academic. The literature reveals a lack of critical accounts on these OR–problems.

11.1 Dynamic Programming without application

Dynamic Programming designs models of optimal decisions over time and assumes a fixed future time horizon. As a RAND researcher, the mathematician Richard Bellman first published on this subject in 1957 and found many imitators.[181] It was assumed that Bellman could repeat Dantzig's success with a new

[178] Bodin, Lewis: Twenty Years of Routing and Scheduling, in: Operations Research, 38 (1990), Heft 4, p. 571–579.
[179] Lück, Wolfgang: Logistik und Materialwirtschaft, Berlin 1984, p. 437–473. Zum Problem des gleichen Fahrers siehe ebd., p. 458.
[180] Vahrenkamp, Richard: Markstudie Tourenplanungssoftware, in: Deutsche Verkehrszeitung vom 17. Oktober 2006.
[181] See for example Martin Beckmann, *Dynamic Programming*, Berlin 1968.

approach 10 years after his Linear Programming. This approach explicitly included the time dimension of economic action and divided the future course of time into different periods in which different policy options could be chosen. In a sensational because contraintuitive approach, Bellman first determined the optimal policy in the end period and gradually worked his way back from there to the present time (backward recursion). Dynamic programming was ideal for OR models, since there is no empirical data on future developments, i.e. researchers do not have to work empirically. Like Linear Programming, Dynamic Programming was only able to find optimal solutions with the help of computers because of the complex calculations involved. In 1979, Christoph Schneeweiss pointed out the high main memory requirements of reverse recursion, which could only be met for very small models using the then state of the art computer technology.[182] Thus Dynamic Programming was not in a position to provide calculation programs for the worldwide spare parts supply of the Air Force, as Judith Klein assumed in her study on Cold War Dynamic Programming.[183]

The question why Dynamic Programming was superior to simple decision rules based on uncertain assumptions about future developments, such as investment decisions, remained unanswered. With abstractification, Dynamic Programming transformed uncertain data about the future into seemingly secure, accurate data and does not reflect the curiosity of applying an elaborate, accurate algorithm to uncertain data. Judy Klein's critique of Dynamic Programming as Cold War Science also fails to recognize this weakness of Dynamic Programming.[184]

11.2 The network flow model

The network flow model simplifies the partial differential equations known as Navier-Stokes equations about flowing liquids in tubes developed by engineers and physicists in the 19th century. The network flow model abstractifies the complex Navier-Stokes equations to such an extent that no friction occurs during the transport of liquids in tubes, i.e. the transport is lossless and vortex-free. In this abstractified context, the mathematicians Lester Ford and Delbert Fulkerson were able to formulate the famous duality theorem “Max-Flow-Min-Cut” in 1956.[185] But applications of network flow models remained unknown. The network models of Operations Research were not included in the debate about the network expansion of important infrastructures, such as the electricity grid or the gas pipeline network.

11.3 The Quadratic Assignment problem as mathematical stalinism

The Quadratic Assignment problem was first formulated by the mathematical economists Martin Beckmann and Tjalling Koopmans in a joint article in Econometrica in 1957, which became famous and was cited about 1500 times.[186] Beckmann and Koopmans worked together at the Cowles Commission in

---

[182] Schneeweis, Christoph: Dynamische Programmierung, in: Beckmann, Martin, Günter Menges und Reinhard Selten (Hersg.): *Handwörterbuch der Mathematischen Wirtschaftswissenschaften*, *Teilband Unternehmensforschung*, Wiesbaden 1979, p. 32.
[183] Klein, Cold War, 2007, cf. note 7.
[184] Klein, ibidem.
[185] Lester Ford Jr., D.R Fulkerson: “Maximal flow through a network.” *Canadian J. Mathematics*, 8, 1956, p. pp. 399-404.
[186] Tjalling Koopmans and Martin Beckmann: “Assignment Problems and the Location of Economic Activities.” *Econometrica*, Vol. 25, No. 1 (Jan., 1957), pp. 53-76.

Chicago.[187] Their article deals with an question that only appears at first glance as an economic problem, namely the spatial arrangement of different production plants on given settlement areas. Hypothetical – empirical data were not available – supply relationships are assumed among the enterprises that are included in the model being measured in tons. The spatial distances in kilometres between the factories are known. The question is how the factories should be optimally arranged on the land so as to minimise the transport performance (sum of tonnes*km) when goods are exchanged between the factories. There were also publications at the company level dealing with the arrangement of machinery in an industrial plant with regard to the exchange of intermediate products.[188] The abstractification underlying the Quadratic Assignment problem becomes clear in the one-dimensional goal of minimizing the transport performance. In contrast to Beckmann's assertion that Operations Research can be applied in complicated decision-making situations,[189] the authors Koopmans and Beckmann reduced the complexity of the decision-making situation of the Quadratic Assignment problem to one dimension of transport performance. In a democratic society, the Quadratic Assignment problem is hung in a vacuum. Only soviet planners in Stalinism could gather so much power to take such a one-dimensional approach to the settlement of factories. In democratic societies, however, a large number of criteria are incorporated into location policy. The configuration of factories with machines also has a similarly complex goal bundle, as Gerhard Waescher has demonstrated in his standard book.

In computer science and combinatorial mathematics, the Quadratic Assignment triggered a flood of publications, for example in the Handbook of Combinatorial Optimization, which was last published in five volumes in 2013 and already had predecessor editions.[190] This problem could only be solved exactly up to a problem size of n = 30 by 2013. However, applications with empirical data remain unknown. Axel Nyberg claimed in his lecture on November 15, 2013 at the Abo University in Turku (Finland) that the hospital in Regensburg in Germany, built in 1972, had an optimal layout according to the Quadratic Assignment problem.[191] However, this was only proven in 2000 and could therefore not have played a role in the construction.

11.4 Computed meals as mathematical entertainment

To attach a semblance of application, Dantzig invented new OR–problems to be solved with the aid of Linear Programming: the diet problem and the traveling salesman problem. Here I will focus on the diet problem. This problem was invented by the later Nobel Prize winner and economist George Stigler in 1945. It is a strange problem: How to nourish a person sufficiently

---

[187] Mirowski, Machine Dreams, (cf. note 6), p. 252.

[188] Waescher, Gerhard: *Innerbetriebliche Standortplanung bei einfacher und mehrfacher Zielsetzung*, Wiesbaden, 1982.

[189] “Mathematical methods are finding ever more applications in the economic and social spheres, especially where decision-making in complicated situations is at stake. Operations Research in particular, which involves the application of mathematical models for economic decisions, has developed rapidly due to this need...”, (translated from German by R.V.) in: Beckmann, Martin, Gunter Menges und Reinhard Selten (eds.): *Handworterbuch der Mathematischen Wirtschaftswissenschaften, Teilband Unternehmensforschung*, Wiesbaden 1979, preface.

[190] Burkard, Rainer: “Quadratic Assignment Problems.” In: *Handbook of Combinatorial Optimization*, pp. 2741-2814, edited by Panos M. Pardalos, Ding-Zhu Du and Ronald L. Graham, Springer Verlag, 2013. Burkhard supplies a bibliography: Burkard, Rainer: “Quadratic Assignment Problems.” In: *Handbook of Combinatorial Optimization*, pp. 2741-2814, ibidem.

[191] Nyberg, Axel: “Applications of the Quadratic Assignment Problem”, see: http://web.abo.fi/fak/tkf/at/ose/doc/Pres_15112013/Axel%20Nyberg.pdf.

for the lowest cost? Stigler contrasted the content of nutrients in various foods (such as vegetables, fruit and meat) with the cost of its procurement and asked how to serve a meal for a person with sufficient nutrients at the lowest cost.[192] Stigler's paper exists in a vacuum and is not linked to the economic situation of the US in 1945. Many consumption goods were rationed due to the war. The municipal and state run programs on social welfare focussed on poor people. Did Stigler want to reduce the cost of these programs? Why did Stigler search for the lowest cost, not for the second lowest or even the maximum cost? The strange diet problem survived for many decades in Operations Research textbooks, without any explanation as to why it might be useful. Dantzig even bothered John von Neumann for help in solving the diet problem. In his von Neumann biography Bhattacharya did not regard the curiosity of the diet problem but regards it as a serious scientific problem.[193]

In 1947, Jack Laderman of the Mathematical Tables Project in the National Bureau of Standards solved the diet problem with the new technique of Linear Programming. His approach consisted of 9 equations and 77 variables, and he solved it with the aid of office calculators, as an academic exercise without application. Dantzig devoted even a chapter in his 1963 book to this problem. Even on IBM's high speed digital computer 701, he coded the problem at the RAND Corporation, but his computed meals were never served to the pilots of Dantzig's employer, the Air Force. Dantzig did not recognize the double curiosity of applying advanced computational techniques to an invented problem based on only weak data – a problem that was neither posed by industry, councils nor the Armed Forces. As empirical data, he displayed in his book a table with nutrients, where the content of ascorbic acid varied by more than 100 percent between various types of apples.[194] So Dantzig could not answer the question of whether a pilot should eat one or two apples each day. Whereas the MPI–group regarded the diet problem as a serious scientific problem, one can criticise by stating that Dantzig's procedure lowered the cutting edge technology of high speed digital computers to the level of a toy, made purely for mathematical entertainment.[195]

11.5 The transportation problem as an abstractification

The transportation model discussed in the following shows the paradox that its discoverer was awarded the Nobel Prize in Economics, but that his model was never applied in economic reality. The reasons for this failure will be explained. One can generalise this case to the effect

---

[192] George Stigler, "The Cost of Subsistence." *Journal of Farm Economics*, vol. 27, 1945, no. 2, pp. 303-314.
[193] Ananyo Bhattacharya: The Man from the Future. The Visionary Life of John von Neumann, Allan Lane 2021, Penguin Books 2022, p. 191.
[194] George Dantzig, *Linear Programming*, (cf. note 58), pp. 551-553. Georg Dantzig, "The Diet Problem." *Interfaces*, vol. 20, 1990, no. 4, 43-47.
[195] Paul Erickson et al., *How Reason Almost Lost Its Mind*, (cf. note 7), p. 65.

that the transportation model stands for many other models of the OR whose relevance is always only claimed. The transportation model is treated as such in OR and business administration. In economics it runs under the heading of the optimal use of resources, for which Koopmans received the Nobel Prize in economics. On both levels, however, the model is the same.

The Transportation Problem (or Model) is always an important chapter in every textbook on Operations Research and every curriculum of Management Schools and describes how to distribute the transportation of goods between various sources and destinations in order to minimize the total costs of transportation.[196] It describes, as a drastically simplified static model without including the time dimension, how transportations of a homogeneous good between different sources (for example wholesale) and destinations (for example retail) should be organized at a given constant transportation cost per ton so that the total transportation cost is minimal. The model is visualized in figures 1A and 2. The model contrasts suppliers and destinations and is based on transportation relations that run from suppliers to destinations. On these transportation relations, different cost rates per ton prevail, which can result from the different distances between suppliers and destinations. It should be emphasized that these cost rates are constant and do not depend on the transported quantity or on the passage of time. Furthermore, the quantities offered are given for the different suppliers and the quantities demanded for the different destinations. In the model it is assumed that the sum of the offered quantities is equal to the sum of the demanded quantities (equilibrium conditions). However, if there are differences in these sums, equilibrium can be reached by inserting dummy suppliers or dummy demanders. Within this model it is discussed how solutions look like, which bring supply and demand over the transportation relations to the equilibrium at minimal sum of transportation costs. Specifically to mark a solution, the question is to be answered, which transportation quantity is to be transported on the relation from supplier i to destination k. The sum over all transportation costs (quantity times cost rate) on each relation is to be calculated. This sum is the (total) cost of the considered solution. Among the different solutions, the solution with the lowest total cost among all other solutions is sought (optimal solution).

[196] George Dantzig, “Linear Programming”, (cf. note 58), chapter 14. Dorfman et al., *Linear Programming*, (cf. note 56), chapter 5.

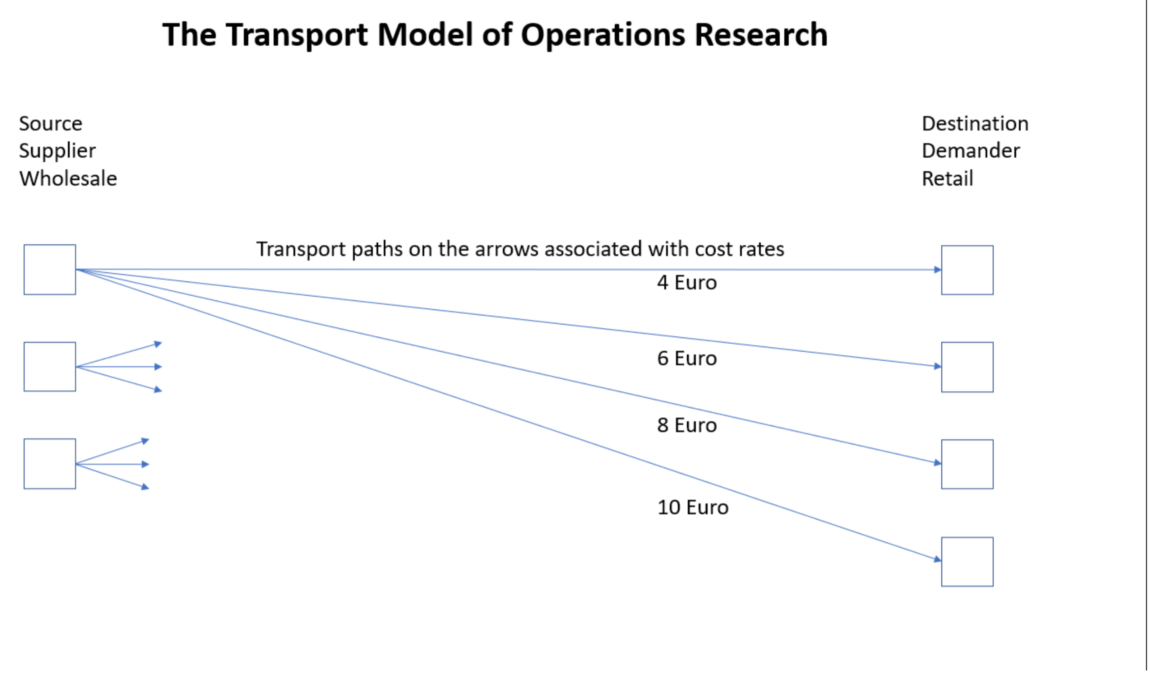


Figure 1A: The Transportation Model (source: own drawing)

Regarding the Transportation Model, one can reveal the nominal nature of this problem. The economic world is used to identifying and abstractifying transportation problems and converting them into simple mathematical models for the academic world, without the intention of solving a problem in the real world.

Churchman et al. suddenly introduce the transportation problem in their textbook using the example of empty wagon coordination of railway companies, without giving any empirical basis for this example.[197] They merely use the reference to railways to give themselves an empirical appearance. Dorfman et al. claim in their textbook that there are numerous applications of the transportation problem in economics and business without providing any evidence to support this.[198] They call one of their examples "purely fictitious".[199] In their textbook "Einführung in die Unternehmensforschung" Henn and Künzi completely dispense with an economic interpretation of the transportation model and merely give the mathematical model. Their approach does not make it clear what the transportation model has to do with corporate research. Dantzig also refrains from elaborating on the economic

[197] Churchman et al., Introduction, p. 283.
[198] Dorfman et al, Linear Programming, p. 106.
[199] A.a.O., p. 117.

benefits of the transportation model in his textbook on linear programming. Instead, he simply speaks of an optimal transportation plan.[200]

The transportation model was invented independently by the mathematicians Frank Hitchcock and Tjalling Koopmans in 1941 and 1942. [201] During the Second World War, Tjalling Koopmans, who received his doctorate as a mathematical physicist in the 1930s, formulated precursors of the so-called transportation model. As a statistician on the Combined Shipping Board in the U.S. during World War II, he observed bottlenecks in the transportation chain of worldwide ship circulations and asked which ship connections could be reduced in capacity if additional shipping space was needed for another connection.[202] He reformulated these bottlenecks into a simple transportation model in which marginal costs of transportation could control the optimization of shipping routes. To give himself an empirical basis, he based his model on statistics from the German Reich Statistical Office in Berlin, which had published the incoming and outgoing quantities (in millions of metric tons) of dry cargo in the world's 15 most important ports in 1925 (The harbor Hamburg is omitted), see figure 1B.

---

[200] Dantzig, Linear Programming, p. 299.

[201] Zu Hitchcock siehe Hitchcock, Frank: The Distribution of a Product from several Sources to numerous Localities, in: Journal of Mathematics and Physics, vol. 20, 1941, p. 224–230.

[202] Exchange Ratios between Cargoes on Various Routes (Non-Refrigerated Dry Cargoes). Memorandum for the Combined Shipping Adjustment Board, Washington, D.C., 1942. Publ. in Scientific Papers of Tjalling C. Koopmans, Springer Verlag, herausgegeben von Martin Beckmann, Berlin 1970, pp. 77-86.

Net receipts of dry cargo in overseas trade, 1925

Unit: Millions of metric tons per annum

(1)	(2)	(3)	(4)
Area represented by[1]	All cargoes other than mineral oils		
	Received	Dispatched	Net receipts
New York	23 ·5	32 ·7	–9 ·2
San Francisco	7 ·2	9 ·7	–2 ·5
St. Thomas	10 ·3	11 ·5	–1 ·2
Buenos Aires	7 ·0	9 ·6	–2 ·6
Antofagasta	1 ·4	4 ·6	–3 ·2
Rotterdam*	126 ·4	130 ·5	–4 ·1
Lisbon*	37 ·5	17 ·0	20 ·5
Athens*	28 ·3	14 ·4	13 ·9
Odessa	0 ·5	4 ·7	–4 ·2
Lagos	2 ·0	2 ·4	–0 ·4
Durban*	2 ·1	4 ·3	–2 ·2
Bombay	5 ·0	8 ·9	–3 ·9
Singapore	3 ·6	6 ·8	–3 ·2
Yokohama	9 ·2	3 ·0	6 ·2
Sydney	2 ·8	6 ·7	–3 ·9
Total	266 ·8	266 ·8	0 ·0

Source: *Der Guterverkehr der Weltschiffahrt,* Statistisches Reichsamt, Berlin, 1928.

Figure 1B: Cargo Traffic (Source: Koopmans, Tjalling: Optimum Utilization of the Transportation System, in: Proceedings in the International Statistical Conference, Vol. 5, Washington D.C. 1947. (Reprint in: Econometrica, vol. 17, 1949, pp. 136–146, Supplement, p. 136), according to Statistisches Reichsamt (ed.): Der Güterverkehr der Weltwirtschaft, Berlin 1928).

However, Koopmans lacked transportation prices in world trade, and he could not solve the model without this data.[203] Although derived from the war economy, in which there was no economic competition, Koopmans relied on a theorem by M. Allais, according to which under competitive conditions the ratio of prices for transportation services optimally corresponds to the ratio of marginal costs.[204] He shows, however, that regardless of competitive conditions, marginal costs can have a steering effect towards the optimum. The optimum is a transportation plan in which the sum of transportation costs is minimal. He published the model under the title "Optimum Utilization of the Transportation System" in the prestigious journal Econometrica in 1949. His paper has been cited over 500 times according to Google Scholar.

[203] Koopmans, Optimum Utilization, 1949, p. 139.
[204] Koopmans, Optimum Utilization, 1949, p. 136.

For this model he received the Nobel Prize for Economics in 1975 (together with the Russian mathematician Leonid Kantorovich for his discovery of linear programming).[205] Martin Beckmann had paved the way for the Nobel Prize in 1975 with the publication of the scientific papers of Tjalling Koopmans in one volume at Springer Verlag in Berlin in 1970.[206] In 1954, Abraham Charnes and William Cooper developed a solution for the transportation problem in the context of linear programming, which became known as the Stepping Stone Method. This work was commissioned by the Office for Naval Research, as the authors state.[207] But no special utility of this method for the Navy is known.

The transportation problem abstracts the real world in different stages. For a homogeneous good ("dry cargo" of world shipping) it compares different suppliers with different demanders, whereby the transportation costs per tonne from supplier i to the demanders k are given. In a process of simplification, the diversity of goods is eliminated and only one homogeneous good is considered, so that it is irrelevant for a customer which supplier supplies him. It abstracts from different types of goods and also from temporal changes in transportation that occur in the real world. It also abstracts from the economies of scale that prevail in the transportation industry, where freight rates are higher for one ton than for 1000 tons.[208] The model is also unable to represent the temporal fluctuation of freight rates. The drastic simplification of the economic reality in the transportation model is in contrast to the claim of the OR promoter Martin Beckmann that OR is particularly applicable in complicated decision-making situations:" Mathematical methods are finding more and more applications in the economic and social field, especially where decisions in complicated situations are to be made. Especially corporate research, which is concerned with the application of mathematical models for economic decisions, has developed...rapidly due to this need".[209]

In the transportation model, supply and demand can even be graphically compared in a table. The abstract model of linear optimization could thus be illustrated with a table, as the following figure from the book by Churchman et al. on page 290 shows.

[205] Siehe die Pressemitteilung der Schwedischen Reichsbank unter: https://www.nobelprize.org/prizes/economic-sciences/1975/press-release/

[206] Scientific Papers of Tjalling C. Koopmans, Springer Verlag, herausgegeben von Martin Beckmann, Berlin 1970.

[207] Charnes, Abraham and William Cooper: The stepping stone method of explaining linear programming calculations in transportation problems, in: Management Science, 1(1), 1954, p. 49-69.

[208] Richard Vahrenkamp already pointed out the fading out of Economies of Scale in his lecture at the annual conference of the Society for Operations Research 2008 in Augsburg.

[209] Beckmann, Unternehmensforschung 1979, Vorwort.

TABLE 11-5b. SECOND FEASIBLE SOLUTION: $C = 233$

Origins \ Destinations	D_1	D_2	D_3	D_4	D_5	Total
S_1	(3)	(5)	(0)	(1)	7	9
S_2	−11	[−13]	(4)	18	0	4
S_3	−10	−1	1	(5)	(3)	8
Total	3	5	4	6	3	21

Figure 1C: Table of Churchman et al.

Churchman et al. enthusiastically show on page 283 how the complicated approach of linear optimization can be simplified with the transportation model and thus be brought closer to the mathematically little pre-trained management. The transportation model was an important marketing argument for Operations Research: "Look - Operations Research is quite simple!" This was the message.

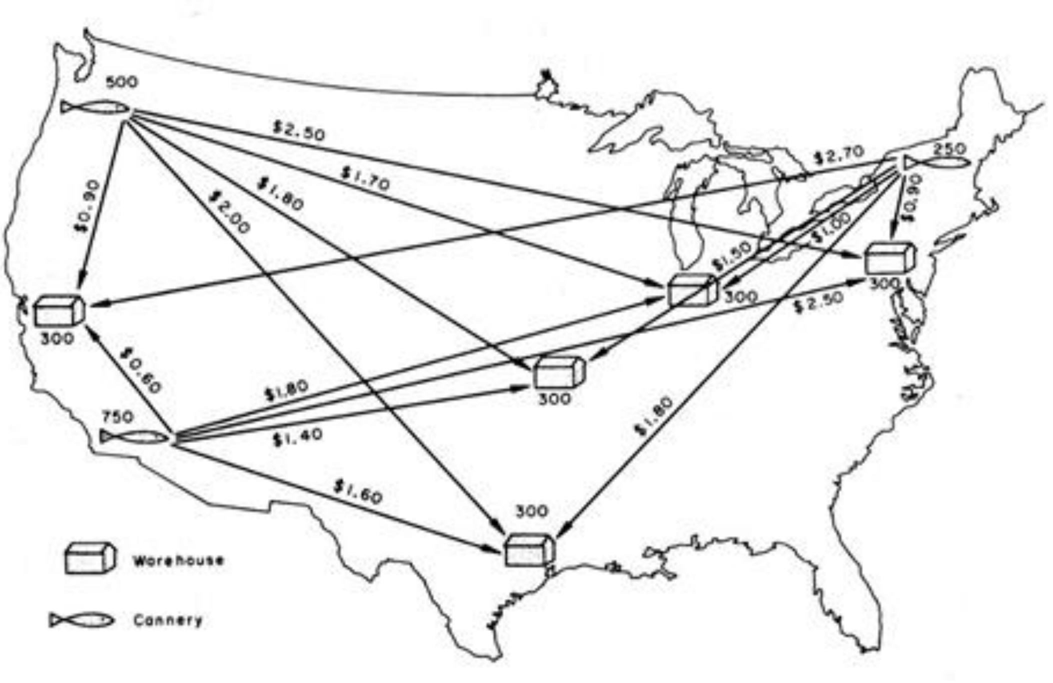
The so-called network simplex algorithm could be applied to the transportation model, which can run completely in the integer range, since it is only about addition and subtraction of quantities, but not about division. This limitation to simple additions and subtractions was ideal for operations research, because it allowed a wealth of textbook examples to be generated without the need to resort to a computer. These examples were also ideal for exercises in university courses, which could use transportation tasks to suggest applications to students. Students could solve a problem in an exam with paper and pencil without a computer. Dorfman et al. emphasize this simple solution method with paper and pencil as a special feature of the transportation problem.[210] Churchman et al. even suspected that this simple arithmetic structure of the "pre-computer age" was suitable for letting simple office workers work through problems.[211] The authors thus indicate that in 1957 they were mentally still in the pre-computer age. Even William Thomas uncritically presents the transportation problem in his history of OR as a success story.[212]

In addition, the transportation problem can be impressively illustrated graphically, e.g. with a map of the U.S., as Georg Dantzig has already done on page three of his book, underlining the economic importance of his book. There he shows the locations of five warehouses and three

[210] Dorfman et al, Linear Programming, p. 106.
[211] Churchman et al., Operations Research, p. 298.
[212] Thomas, Rational Action, p. 181.

fish processing factories of the fish canning industry. He also shows transportation relations between these locations and the transportation costs per tonne there:

Figure 2 The Transportation Problem in Dantzig's book 1963. Transportation inside the US between canneries and warehouses with transportation rates.[213] (Source: George Dantzig: *Lineare Programmierung und Erweiterungen*, (German edition) Springer Verlag, Berlin, 1966, p. 3)[214]



It is surprising that Dantzig specifically chose the fish canning industry as an example in a highly industrialised country with a strong high-tech industry like the U.S. instead of, for example, locations of warehouses for spare parts in the aircraft industry. It is possible that Dantzig was referring to John Steinbeck. John Steinbeck received the Nobel Prize for Literature in 1962 for his novel Cannery Row, published in 1945, which describes the fish canning industry on the US West Coast in Monterey - one year before Dantzig's book was published.

Also in Monterey, in 1951, the Navy set up a large OR department in the Navy Postgraduate School, which, according to OR promoter Saul Gass, became the largest OR department in the U.S. and even the world.[215] If this assessment is correct, the thesis could be supported that Operations Research served to give the U.S. military a scientific outfit, with empirical

---

213 Also in their joint paper "A Model of Transportation" Koopmans and Reiter showed maps of shipping routes of the world, 245s, in Koopmans, *Activity Analysis*, (cf. note 60), pp. 222-259.

214 That Dantzig chose canneries as example reminds to John Steinbeck's book Cannery Row playing in Monterey. Steinbeck received the Nobel Prize in 1962 – one year before Dantzig's book appeared.

215 Lecture of Saul Gass on the yearly meeting GOR in 2008 in Augsburg, see http://www.gor-ev.de/or-2008-in-augsburg. (access on 30 May 2018).

usefulness of OR methods being secondary. Dantzig probably aimed his map at the large OR Navy base in Monterey in order to attract attention for his book.

As a nominal approach, Dantzig produced this map as an invention on his office desk, but not from empirical data of a contract with a cannery firm. While the map calls upon the authority of an important economic problem, this impression is misleading. Like Game Theory, until now, no application of the Transportation Problem has been published. Koopmans abstractified this problem so heavily that it remains in the world of numbers and could not gain traction in the real world. In the capitalistic economy, no enterprise in the transportation trade (ship, aircraft, railway, motor truck) called for a project to optimize routes by the transportation problem. The Eastern Bloc fell for the optimisation brilliance of the Transportation model and in the 1960s intensively brought it to mainframe computers. For application in the Eastern Bloc see below, section 12. The resistance against the implementation of the transportation model in the Eastern Bloc is based on the fundamental question of how rationalization gains in the transportation model can be distributed at all. If all consignors belong to one company or all consignees belong to one company, it can be assumed that rationalization gains that arise from finding the minimum cost in the transportation model can be credited to the consignor or consignee. The situation is different when different players are likely to appear on both the sender and the recipient side. Koopmans had not considered this situation in his transportation model at all, but only naively sought the cost minimum without considering a social context.

Remarkably, many OR textbooks did not apply a spreadsheet software to present and compute the transportation problem but preserved old-fashioned methods for finding an optimal solution. The north-west rule and the stepping stone method were outdated in the age of spreadsheet software, where one can apply Excel's Visual Basic to determine dual variables.[216] In the mainframe software packages for linear programming in MPS format, the transportation model was not included at all, since it did not exist in the real world.[217]

In the academic field of Operations Research, scholars were interested in their models but not in application, and so the question did not attract their attention in the 70 years since its discovery of 'why' the Transportation Problem is insufficient to be applied to problems in the world of economy. At first sight, the coordination of empty railcars in a railway company to be sent back to the sources of material seemed to be an appropriate application for the Transportation Problem. However German Railways did not coordinate their trains loaded with coal but rather used shuttle trains between the sources of coal and consumption destinations. Empirical research into railway systems revealed the time structure of

---

[216] See OR–Lecture of Daniel Lambert on www.wiwiweb.de: https://www.wiwiweb.de/operations-research/transport/stepp-stone-methode.html

[217] Walter Dürr und Klaus Kleibohm: Operations Research, first edition, München 1983, p. 212.

transportation. The railway company needed forecasts for the demand of empty railcars that the Transportation Problem could not provide.[218]

11.6 The travelling salesman as invention

In the United States of the 1940s, the profession of the traveling salesmen was held in high esteem by the public. Dantzig took this up when he invented the so–called traveling salesman problem. Also, this famous problem arose in the academic environment of the RAND corporation as an invention of the mathematician Dantzig to shed some light of application on Linear Programming, but not as a contract with a firm that wanted to improve its sales organisation. At RAND, the Travelling Salesman problem was seen as an additional intellectual challenge to game theory. Dantzig abstractified a problem of the daily life of a traveling salesman to visit customers and proposed with a small semantic shift that a traveling salesman has to visit not a number of customers but a number of cities. Danzig's question was how to organise the travel visiting these cities with the least sum of distances to be travelled. The RAND researchers, the mathematicians George Dantzig, Delbert Fulkerson and Selmer Johnson, proposed on their office desk a route through the 48 states of the United States where they picked for each state one city. The route contained even the thinly populated state of Montana with less than half a million inhabitants where a salesman could hardly sell products in contrast to heavily populated states as California or Pennsylvania.[219] In addition, the district Washington D.C. was merged into the route – a route that a traveling salesman in the physical world never would travel. The road distances between the cities were derived as "desktop research" from a road atlas.[220] The proposed route through the 48 states of the United States did not serve a sales organisation to guide its salesmen but was a good marketing story of Dantzig as he – supported by a map of the United States – appealed to the national proud of US citizens in every state. He showed that Linear Programming is a unifying tie connecting the single states. Gass and Assad made the humorous remark in their timeline: "See the U.S. in a Chevrolet", underlining the not very serious approach of the Travelling Salesman problem.[221] In the last 60 years the traveling salesman problem, with its semblance of application, fascinated mathematicians with a steady growing number of cities to be visited – parallel to the rising computing power of digital computers – until by the year 2017 they considered a route through 1.9 million cities of the world. Empirical surveys on the need for solution methods for the Travelling Salesman problem in industry remained unknown. From the great manufacturing firms, like Volkswagen or Siemens, no statement is known, that the use of advanced solution techniques, besides then simple heuristics of nearest neighbor and 2-opt, for great Travelling Salesman problems would result in substantial savings in costs for production or cost for logistics. The leading OR scholar in Germany, Andreas Drexl, who was the leading researcher at the University of Kiel (Germany) according to the press release of his University of Kiel, reported in a press interview that he was impressed by the beauty of the Travelling Salesman problem. Merill Flood reported in his paper that

---

[218] Michael Gorman, "Empty Railcar Distribution." In Bruce W. Patty (ed.), *Handbook of Operations Research Applications at Railroads*, New York 2015, pp. 177 – 190.

[219] In their book Business Statistics, the authors Riggleman and Frisbee emphasize the importance of population density to generate the demand for consumer goods that is important for a travelling salesman. John Riggleman und Ira Frisbee: Business Statistics, London 1938, p. 428.

[220] G. Dantzig, R. Fulkerson and S. Johnson, "Solution of a Large-Scale Traveling-Salesman Problem." RAND Research Memorandum, P 510, April 1954.

[221] Gass and Assad, *Timeline*, 2005 (cf. note 12), p. 48.

he had heard of applications.[222] But the justification for every new generation of supercomputers or even quantum computers refers to the alleged need to solve great Travelling Salesman problem for production or logistics.[223]

12 The boom in transport optimization in the German Democratic Republic

The application of OR methods in the Eastern Bloc was characterized by political knowledge cultures. While in the Soviet Union the use of mathematical planning methods – also known as cybernetics – in the national economy was initially rejected as "Western" in the early 1950s, Nikita Khrushchev's criticism of Stalin at the 20th Party Congress of the CPSU in 1956 and with a conference on economic mathematics in Moscow in 1959 changed the attitude.[224] In 1967, George Dantzig, then professor of OR at Stanford University, estimated that in the Soviet Union several times as many mathematicians, OR researchers and computer science researchers were working in relation to the U.S. in order to catch up in the production of goods.[225]

In the German Democratic Republic (GDR), communist party (SED) leader Walter Ulbricht was sceptical about cybernetics and data processing at the beginning of the 1950s, but at the end of the 1950s he became the promoter of cybernetics and data processing. Cybernetics as a systems science has now been widely discussed. In 1964 the international conference "Mathematics and Cybernetics in Economics" took place in East Berlin.[226] The computer was seen as an ideal tool of the planned economy.[227] In 1963, the GDR Council of Ministers called for the establishment of a computer-assisted accounting system for the national economy in the guideline for the New Economic System of Planning and Management of the National Economy.[228] Even the Swiss OR promoter Hans Künzig was able to publish a paper on

---

[222] Press release University Kiel on 28 November 2005. Handelsblatt on 12 December 2005. "Flood, Merrill: The Traveling-Salesman Problem." *Operations Research*, Vol. 4, No. 1 (Feb., 1956), pp. 61-75., here p. 65.
[223] http://www.math.uwaterloo.ca/tsp/world/.
[224] On the debate on cybernetics in the 1950s see Seising, Cybernetics, 2010. On cybernetics in the USSR see Gerovitch, Cybernetics, 2002, here p. 155. Brusbeck, Unternehmensforschung, 1965, p. 46.
[225] Dantzig, Operations Research in the World, 1967, p. 117.
[226] Dittmann/Seising, Cybernetics 2007. Mathematics and Cybernetics in Economics, International Conference in Berlin in October 1964, Proceedings, Akademie-Verlag Berlin 1965.
[227] Donig, DDR-Computertechnik, 2006, p. 252. Potthoff, linear programming, 1961. Nützenadel, economists, 2005, p. 201.
[228] The directive peculiarly spoke of "highly mechanized computing systems". In the "Prague Spring" of 1968, Rudi Dutschke, the leader of the rebellious West Berlin students who grew up in the GDR, told the astonished students of the University of Prague who, after 20 years of communism, were actually striving for a market economy control of the economy that the planned economy was the superior system thanks to the IBM computer S/360, see Stepan Benda's memories of his meeting with Rudi Dutschke in Prague at https://www.tschechien-

mathematical optimization with FORTRAN and Algol programs in the GDR in 1966 at the Leipzig publishing house Teubner Verlag.[229]

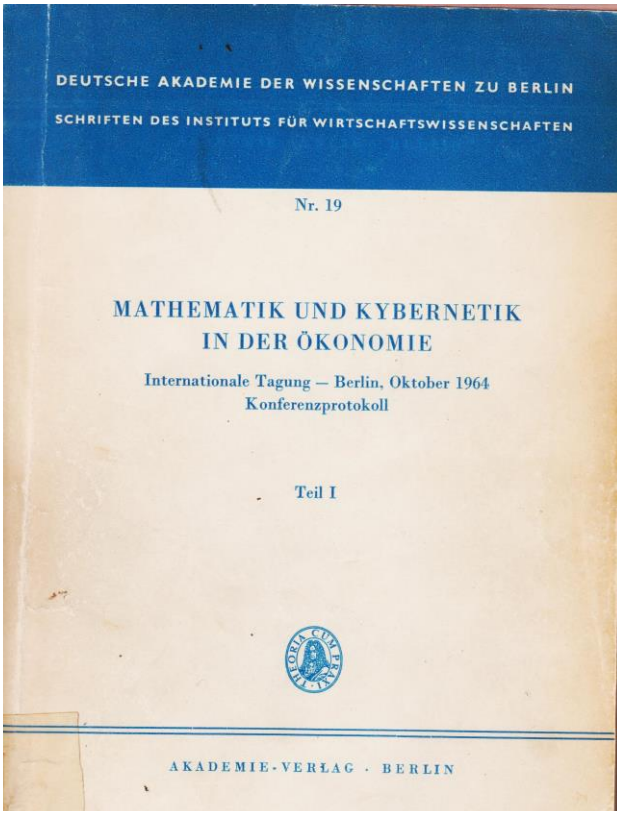


Figure 3: Volume Mathematik und Kybernetik, 1965

Among the multitude of cybernetics methods, I will pick out the computer-aided transport optimization here. The entire Eastern Bloc experienced a boom in transport optimisation at the beginning of the 1960s. In contrast to the capitalist world, methods of computer-aided transport optimisation, such as route planning and the transport model, were eagerly adopted in the Eastern Bloc, as they seemed to correspond to the simplifying approaches of the planned economy. As emphasized by the chairs of Economic Policy at universities in Western–Germany, the planning approaches of central administrative economies can be characterized by simplification. The broad variety of goods that characterizes Western markets is reduced to only a few types of goods.[230] During the reform era of the GDR from 1961 to 1970, numerous books on socialist economic management with the help of Operations Research were published. The reform fraction in the SED understood this approach as organizational science

---

online.org/blog/meine-begegnung-rudi-dutschke-im-april-1968-prag-01082016-17424. (accessed on 30 May 2018).

[229] Hans P. Künzi, Hans G. Tzschach, Carl A. Zehnder: Numerical Methods of Mathematical Optimization: with ALGOL and FORTRAN Programs, Leipzig: Teubner, 1966.

[230] Eucken, Economic Policy, 1990, p. 78.

in order to be able to properly manage the large socialist corporations, such as the "Vereinigung volkseigener Betriebe" (VVB), within the framework of the New Economic System of the 1960s.[231] From Operations Research, the SED expected management guidance, as Herbert Simon had suggested. Since 1967, the universities had the field of study "Marxist-Leninist Organization Studies" (MLO), in which Operations Research played a major role.[232] The SED had been so hasty in founding the corporations "Vereinigung volkseigener Betriebe" that it lacked methods for managing these large conglomerates. The MLO seemed to offer a way out.

In the following, the social spaces of transport optimisation are dealt with. Since 1959, at party conferences of the SED and in recommendations of the highest management bodies of the GDR, reference was repeatedly made to existing "unnecessary, contrary and uneconomical transports" in the national economy, for example the transport of timber from the southern part of the GDR to the northern part and at the same time from other timber sources transports from the north to the south. These kinds of transport had to be identified and eliminated using modern methods in order to achieve a high economic benefit.[233] In numerous research institutions, such as the Central Institute for Automation in Dresden and the Dresden University of Transport, Building and Urban Affairs, these political guidelines were gladly accepted.[234] Karl Hofmann studied the supply relationships in the basic industry at the University of Transport and Communications in Dresden and established optimised supply relationships for wood, coal, sulphuric acid and building materials based on railway transport using the transport model. He awarded numerous diploma theses and dissertations. However, the extent to which the optimisations remained merely academic and were not implemented remained open.

In the coal industry, the abstractification in the model did not succeed smoothly, as many coal types had to be distinguished. Furthermore, the data set for the distribution of lignite briquettes was too large for the approximately 50 thousand bit drum memory of the digital

[231] Gert-Joachim Glaeßner: Herrschaft durch Kader: Leitung der Gesellschaft und Kaderpolitik in der DDR am Beispiel des Staatsapparates, Opladen 1977.

[232] Hartmut Schulze: Kybernetik und die Ausbildung der Ökonomen in der DDR, in: Dittmann, Frank und Rudolf Seising, Kybernetik, 2007., p. 433–445.

[233] Hofmann/Schreiter/Vogel, Optimierung, 1964, p. 6. These authors as well as Potthoff (Linearprogrammierung, 1961) give extensive bibliographies with sources from Poland, Hungary, USSR and Czechoslovakia.

[234] Further research institutions took part in transport optimisation: The Test and Development Centre for Motor Traffic in Dresden, the Institute for Transport Research in Berlin, the University of Architecture and Civil Engineering in Weimar, the Institute for Economics of the German Building Academy in Leipzig, the State Planning Commission and the National Economic Council, see Hofmann et al., ibid., p. 7. See also K. Kohlmay's opening lecture on the congress "Mathematics and Cybernetics in Economics", in: Deutsche Akademie, Mathematik und Kybernetik, 1965, pp. 4-11.

computer ZRA1, manufactured by Carl Zeiss in Jena, which was common in the GDR at that time. The number of coal suppliers had to be reduced from 50 to 21, as did the number of customers from 3000 to 74.[235] The optimisation programme also achieved unsatisfactory solutions for the supply of pine wood. Small wood-processing companies were assigned to distant wood sources, which resulted in high transport costs for the companies and caused resistance to optimisation.[236] Figure 4 below shows the coordination of lime deliveries in the GDR.

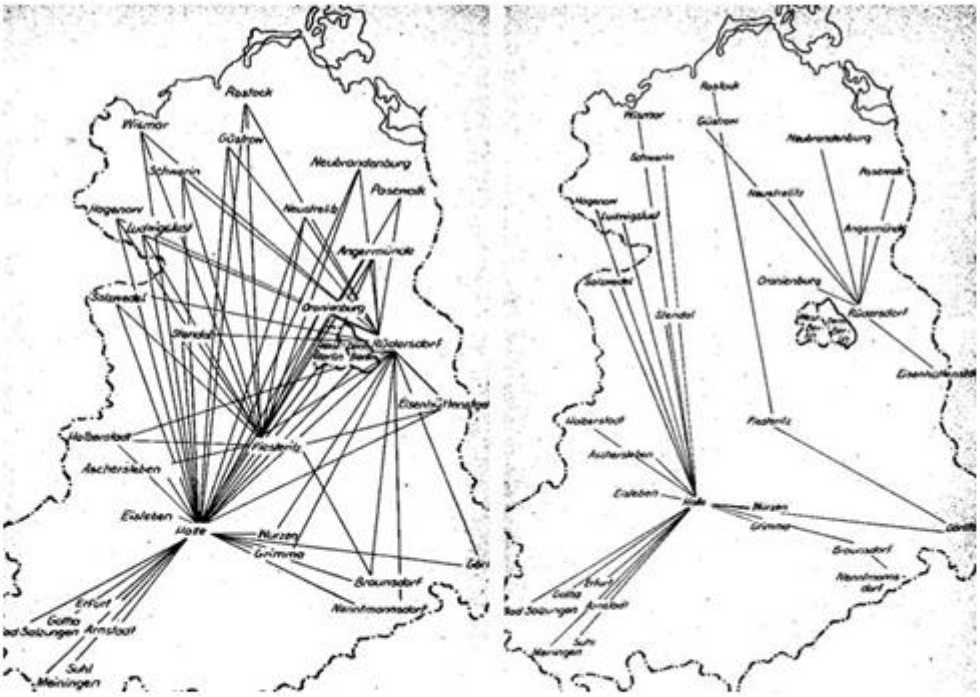


Figure 4: Centralization of transport relations for lime in the GDR

At the end of their publication, the authors Hofmann et al. also report on obstacles that stand in the way of abstractification in the transport model: The customers were to be convinced of the changed supply relationships and any necessary organisational or technical changes were to be discussed with them. In contrast to the optimizers' desire for stable supply relationships, changes in quantities and quality requirements are constantly occurring in lively economics. Long-term supply relationships in the state distribution offices, sales offices and associations of state-owned enterprises were changed without these enterprises benefiting from the advantages of optimisation.[237] In the research reports of the Test and Development Centre for Motor Traffic at the Dresden University of Transport and in the journal "Der

[235] Hofmann et al., ibid., p. 72.
[236] ibid., p. 90.
[237] ibid., p. 101.

Verkehrspraktiker", it was also acknowledged that so far there have been few applications of the transport model, but examples of the supply of flour to bakeries in Dresden and the supply of bricks to construction sites have been mentioned.[238]

Hannelore Fischer reported in her book "Operation Research in the Socialist Economy" on the use of the transport model in forestry.[239] In her research area of Königs Wusterhausen she looked at 130 forestry operations that felled trees and transported them to 20 sawmills. She collected data on logging and transport services. In order to sufficiently abstractify, softwood and hardwood trees were considered separately. The project required 20 hours of computing time on the computer ZRA1 to find the cost-minimum transport allocation. The computer was located at the observatory Potsdam-Babelsberg. The Vogel approximation method was used to solve the transport problem. This program was programmed in the computer center of the Deutsche Reichsbahn and was in use since 1965. Another program variant after Dennis was written by the VEB Leuna plant "Walter Ulbricht". Fischer discussed the resistance of the forestry companies to carry out their timber deliveries according to the optimized plans of the transport model. The optimization achieved a saving of transport costs in the order of 238,000 marks, corresponding to 14% of the costs without optimization. The working group of Hannelore Fischer extended her optimization approach to the state forest districts of Belzig, Potsdam and Rathenow. While the optimization lowered the transport costs in the range of 10 - 15%, the transport performance, measured in solid cubic meters of wood multiplied by transport kilometers, even decreased by about 50%. Hannelore Fischer was an OR–scientist habilitated at the University of Jena in 1968 - probably the only female OR–scientist with the rank of professor in Germany, if not in all of Europe.

The resistance to the implementation of the transport model shown by Fischer and Hofmann et al. touches on the fundamental question of how rationalisation gains in the transport model can be distributed at all. If all consignors belong to one company or all consignees belong to one company, it can be assumed that rationalisation gains that arise from seeking the minimum cost in the transport model can be credited to the consignor or consignee. The situation is different when different players are likely to appear on both the sender and the recipient side. Koopmans did not consider this situation in his transport model at all, but only naively sought out the cost minimum without considering a social context. Even in the GDR, there was no optimization god who hovered over the model world and distributed the profits

---

[238] Experimental and Development Centre for Motor Traffic, Methodology, 1964. On pages 25f, the computers accessible for research in the GDR are compiled as a table. Annual reports of the Experimental and Development Centre 1962 and 1963, files of the Ministry of Transport, Federal Archives Berlin, file DM 1/7152. Verkehrspraktiker, 1964, pp. 6-7.

[239] Hannelore Fischer: Operationsforschung in der sozialistischen Wirtschaft: mit bewährten Modellen aus der Praxis, Berlin 1969, pp. 410–427.

of transport optimization. Rather, the companies involved, including the transport companies, were either managed by the central ministries, or managed by the districts, or finally managed by the individual municipalities, among whom the distribution of the rationalization profits would have to be negotiated.

The volume "Methodik für die Optimierung der Transporte mit Kraftfahrzeugen" published in 1964 by the Dresdener Versuchs- und Entwicklungsstelle focused on the transport of goods by truck. In addition to the transport model, the round trip problem ("Travelling Salesman Problem") and the route planning problem based on it are presented there. The route planning problem starts from a central depot and compiles the total number of daily grocery stores in a city into a series of separate delivery routes for delivery vehicles. The following figure visualizes this problem for 10 grocery stores and three tours.

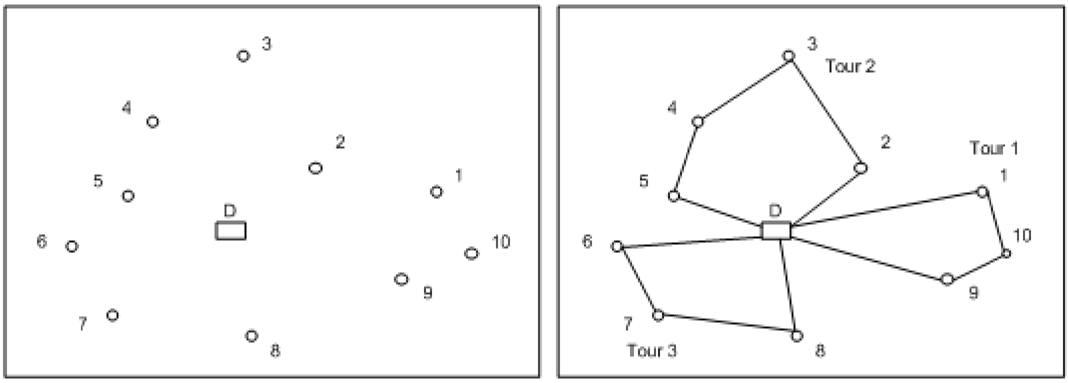


Figure 5: Delivery of 10 grocery stores in a city from a depot D, left without linking tours, right with three tours. (Source: drawn up by the author)

The tour planning problem asks how the stores are to be assigned to individual supply tours and how the shortest sequence of stores to be visited is to be determined in the individual tours - the latter a Travelling Salesman problem (see above).[240] The aim of the planning is to determine a breakdown into daily routes and their sequence in such a way that the total number of kilometres driven by the delivery vehicles is minimised. The individual journeys of the delivery vans starting from the depot were optimized with heuristic procedures for the round trip problem to shortest routes. The application of Dantzig's optimization methods to the roundtrip problem with a computer was rejected, pointing out that this approach would test too many alternatives. Instead, simple heuristics were mentioned which were well suited for "manual calculations".[241] Manual calculations carried out with the table calculator were

[240] Hoffman and Padberg, Travelling Salesman, 1996.
[241] Experimental and Development Centre, Methodology, 1964, p. 20.

unproblematic insofar as the problems were manageable and the individual supply tours seldom included more than 10 retail outlets.

In the Western OR literature, however, it was pointed out that the route planning problem described here was too much simplified as a "basic model" and therefore only suitable for academic teaching and that numerous additional conditions had to be taken into account in real-life applications, such as the return of empties or certain time restrictions on delivery. But precisely these additional conditions, which vary depending on the application, prevented the creation of a generic basic model to which the additional conditions could simply be "stuck". For this reason, the model had to be redefined from scratch for each application.[242]

The authors of the Experimental and Development Centre named the locations of institutions throughout the GDR that provided computers - mostly the ZRA1 - for calculations. These computer locations took over the programming and the actual calculation due to the delivered data, for which 160 German Marks were charged per computer hour and 12 German Marks for a mathematician hour for programming. Users should therefore weigh a "manual calculation" against the computer calculation.[243] The authors also addressed data collection problems. The road network was to be created from map material, with applications for the purchase of maps being submitted to the State Geodesy Control if the maps were not commercially available. The goods to be shipped should be recorded by type and weight. Milk deliveries to retail stores in various cities such as Dresden, Berlin and Rostock are mentioned as an application of the route planning problem. In Dresden there was a shortening of the daily delivery routes from 730 km to 580 km. During the optimisation in Dresden it turned out that the former supply runs overlapped, so that the elimination of the overlaps made it possible to shorten the route without optimisation.[244]

In order to apply the round trip problem to the route planning problems, it was necessary to determine in advance the individual delivery areas in which the individual route was to be optimized. There was no mathematical procedure for this decomposition, as the authors complained in the 1964 volume "Methodik für die Optimierung der Transporte mit Kraftfahrzeugen" on page 19. The British researchers G. Clark and J. Wright did not publish their tour planning data until the same year, 1964, when they were able to determine the delivery areas using the Savings method.[245] Clark and Wright's approach is interesting in that it

[242] Mattfeld and Vahrenkamp, logistics networks, 2012.
[243] Experimental and Development Centre, Methodology, 1964, p. 20, p. 25f. Hofman et al., Optimization, 1964, p. 29.
[244] Experimental and Development Centre, Methodology, 1964, p. 19.
[245] Clarke/Wright, Scheduling, 1964.

starts from an unusual starting solution, the one that is the worst of all: Each shop is served by a truck in a shuttle tour from the depot, without involving the service of other shops. In an iteration process, shuttle tours are combined step by step, which promise the greatest savings in travel distance back to the depot. The authors Hofmann et al. also mention factors that stand in the way of abstractification. This is how the daily fluctuating needs of the grocery stores are called, so that one had to work with rough average values. Separate delivery schedules were recommended for the peak demand on Saturday. The plans for Sunday delivery, however, meant that many stores remained closed, so that new plans had to be drawn up for Sunday.[246]

In the following, we will show how transport optimization was embedded in the political knowledge cultures of the GDR and met with resistance there. Mathematicians in the GDR were sceptical about the use of OR methods. The head of the testing and development centre for motor traffic at the Dresden University of Transport, the mathematician Werner Haering, complained at the 1964 meeting of heads of the motor traffic administrations (BDK) in Magdeburg that the shipping departments of industry was hardly interested in optimising the use of trucks.[247] The negative attitude of the shipping departments resulted not least from the centralisation of truck traffic, which the SED had undertaken since 1959. The industry was deprived of its own truck fleets, which it had used in so-called factory transport, and centralised as state-owned transport companies, which now offered transport services to the shipping departments.[248] The Motor Transport Department of the Ministry of Transport wanted to take action against this hesitant attitude of the loading industry and launch a broad training campaign. Already in March 1963 in Weimar and in June 1964 in Zabeltitz, training programmes for transport optimisation for the shipping departments took place.[249] The mathematical transport optimization met the politicized field of the centralized truck policy of the SED.

In the application of tour planning, the GDR was about 20 years ahead of Western–Germany (FRG). It was not until the 1980s that the main memory of the computers available in companies in FRG, at around 300 kilobytes, was large enough to use route planning software such as the TRAFFIC package from Siemens. This software was used above all in the sales organisations of the financially strong companies in the beverage industry and milk processing. As already known from the centralised transport policy in the GDR, problems with the abstractification of route planning also arose in the FRG. The shops supplied by the delivery vehicles always wanted to be served by the same driver in the recurring routes - a

---

[246] Experimental and Development Centre, Methodology, 1964, p. 19.
[247] Traffic Practitioner, Lack of Interest, 1964, p. 6f.
[248] Vahrenkamp, Dream, 2015.
[249] Verkehrspraktiker, Lacking Interest, 1964, p. 7. Versuchs- und Entwicklungsstelle, 1964, Preface.

wish that the route planning software did not take into account. There were also problems to include shops with different delivery rhythms in a common tour.[250] In the route planning packages, the actual route planning was considerably extended to a truck fleet management system, which included accounting for routes, vehicle costs and personnel deployment. However, high licensing costs for software manufacturers hampered widespread use until the 1990s.[251]

The boom in transport optimisation in the GDR came to an end at the end of the 1960s. Researchers referred to the alleged relevance of the transport problem. The authors Dück et al. justified it tautologically in 1971 as follows: "In the economy the transport problem is given great importance ...because of its great economic significance."[252] By "economy" the authors mean the national economy. However, the researchers could not point to any convincing applications.

[250] For the use of route planning in the beverage industry and in milk processing, see Lück, Logistik, 1984, p. 437-473. For the problem of the same driver, see ibid., p. 458 and Vahrenkamp, Dream, 2015, p. 15.
[251] Vahrenkamp, market study, 2006.
[252] Dück et al., Operation Research, 1971, vol. 2, p. 186.

13 Literature:

50 Years Project Air Force, Washington, D.C., 1996.

Ackhoff, Russel und Herbert Simon (Hrsg.): Proceedings of the Automatic Data Processing Conference, Graduate School of Business Administration, Harvard University, Boston, 1955.

Jon Agar, Jon: The government machine: a revolutionary history of the computer, MIT Press 2003

Davies, Max (ed.): International Conference on Operational Research (Oxford), London 1957.

Akera, Atsushi: Calculating a Natural World – Scientists, Engineers, and Computing during the Rise of U.S. Cold War Research, MIT Press 2007.

Alavi, Maryam und Patricia Carlson: A Review of MIS Research and Disciplinary Development, in: Journal of Management Information Systems, 8 (1992) issue 4, pp. 45–62.

Albach, Horst: Stand und Entwicklungstendenzen der Unternehmensforschung in Deutschland, in: Wissenschaft und Praxis: Festschrift zum zwanzigjährigen Bestehen des Westdeutschen Verlags, Köln 1967, pp. 251–282.

Aspray, William: John von Neumann and the Origins of Modern Computing, Cambridge, Mass., 1990.

Baer, D.: IBM 1400 Series, in: Encyclopedia of Computer Science, edited by Anthony Ralston und Chester Meek, New York 1976, pp. 629s.

Bartsch, Helmut und Thomas Teufel: Supply Chain Management mit SAP APO: Supply-Chain-Modelle mit dem Advanced Planner and Optimizer, Bonn 2000.

Bashe, Charles Lyle Johnson, John Palmer, Emerson Pugh: IBM's Early Computers, MIT Press 1986.

Bhattacharya, Ananyo: The Man from the Future. The Visionary Life of John von Neumann, Allan Lane 2021, Penguin Books 2022

Beckmann, Martin: Dynamic Programming, Berlin 1968. (vol. 9 of the series „Ökonometrie und Unternehmensforschung", edited by Hans Künzi und Wilhelm Krelle).

Beckmann, Martin: Unternehmensforschung heute, Berlin 1971 (Lecture Notes in Operations Research and Mathematical Systems vol. 50).

Beckmann, Martin und Hans Künzi: Lecture Notes Band 170, Berlin 1979 (Lecture Notes in Economics and Mathematical Systems vol. 170).

Beckmann, Martin, Günter Menges und Reinhard Selten (eds.): Handwörterbuch der Mathematischen Wirtschaftswissenschaften, Teilband Unternehmensforschung, Wiesbaden 1979.

Bellman, Richard: Dynamic Programming. Princeton: Princeton University Press 1957.

Bliek, Jan van der (ed.): The AGARD history: 1952 - 1997 / NATO. Advisory Group for Aerospace Research and Development ; Neuilly-sur-Seine, 1999

Bodin, Lewis: Twenty Years of Routing and Scheduling, in: Operations Research, 38 (1990), issue 4, pp. 571–579.

Bradtke, Thomas, Grundlagen in Operations Research für Ökonomen, 2003, München.

Brusberg, Helmut: Der Entwicklungsstand der Unternehmensforschung, Wiesbaden 1965.

Bühlmann. H., H. Löffel und E. Nievergelt: Einführung in die Theorie und Praxis der Entscheidung bei Unsicherheit, Berlin 1968, 2nd edition 1969. (Lecture Notes in Operations Research and Mathematical Economics vol. 1)

Burkard, Rainer und Ulrich Derigs: Assignment and Matching Problems: Solution Methods with FORTRAN-Programs, Berlin 1980 (Lecture Notes in Economics and Mathematical Systems, vol. 184).

Burkard, Rainer: Quadratic Assignment Problems, In: Handbook of Combinatorial Optimization, pp. 2741-2814, edited by Panos M. Pardalos, Ding-Zhu Du und Ronald L. Graham, Springer publisher 2013.

Campbell-Kelly, Martin und William Aspray: Computers – A History of the Information Machine, New York 1996.

Campbell-Kelly, Martin: Number Crunching without Programming: The Evolution of Spreadsheet Usability, in: Annals of the History of Computing, 29 (2007), issue 3, pp. 6–19.

Ceruzzi, Paul: Beyond the Limits – Flight enters the Computer Age, MIT Press 1989.

Ceruzzi, Paul: History of Modern Computing, MIT Press 2000.

Charnes, A., W. Cooper and B. Mellon: Blending Aviation Gasoline. A Study in Programming Interdependent Activities in an Integrated Oil Company, in: Econometrica, 20 (1952), issue 2, pp. 135–159.

Charnes, Abraham and William Cooper: An Introduction to Linear Programming, New York 1953.

Churchman, Charles West, Russell L. Ackoff und E. Leonard Arnoff: Introduction to Operations Research, New York 1957.

Clarke, G. und Wright, J. W.: Scheduling of Vehicles from a Central Depot to a Number of Delivery Points, in: Operations Research 12 (1964), issue 4, pp. 568–581.

Dantzig, George: Impact of Linear Programming on Computer Development, Lecture at ORSA/TIMS meeting on April 30, 1985, typewriter manuscript Stanford University, Document ADA157659, 1985.

Dantzig, George: Linear Programming and Extensions, Princeton University Press, 1963.

Dantzig, George: Lineare Programmierung und Erweiterungen, Berlin, Springer Verlag, 1966. (volume 2 of the series „Ökonometrie und Unternehmensforschung“, edited by Hans Künzi und Wilhelm Krelle)

Dantzig, George: Operations Research in the world of today and tomorrow, in: Operations Research Verfahren, edited by Rudolf Henn, vol. 2, 1965, pp. 113–118.

Davies, Max: Operational Research in Practice, Report of a NATO Conference, edited by Max Davies und Michel Verhust, Pergamon Press London 1958.

Davies, Max (ed.): International Conference on Operational Research (Oxford), London 1957.

Deutsche Akademie der Wissenschaften zu Berlin (ed.): Mathematik und Kybernetik in der Ökonomie, Internationale Tagung in Berlin Oktober 1964, Konferenzprotokoll, Akademie Verlag Berlin 1965 (Schriften des Instituts für Wirtschaftswissenschaften, Bd. 19).

Deutsche Gesellschaft für Operations Research (ed.): Proceedings der Jahrestagungen, Würzburg, verschiedene Jahrgänge seit 1972.

Deutsche Gesellschaft für Operations Research (ed.): Mitgliederverzeichnis, Würzburg 1978.

Dittmann, Frank und Rudolf Seising (eds.): Kybernetik steckt den Osten an – Aufstieg und Schwierigkeiten einer interdisziplinären Wissenschaft in der DDR, Berlin 2007.

Donig, Simon: Die DDR–Computertechnik und das COCOM–Embargo 1958–1973. Technologietransfer und institutioneller Wandel, in: Friedrich Naumann und Gabriele Schade (eds.): Informatik in der DDR, Bonn 2006, pp. 251–272.

Dorfman, Robert: The Discovery of Linear Programming, in: Annales of the History of Computing, 6 (1984), issue 3, pp. 283–295.

Dorfman, Robert; Paul Anthony Samuelson ; Robert M Solow: Linear programming and economic analysis, New York 1958.

Dück, Werner und Manfred Blieferich: Operationsforschung, 3 volumes, Berlin 1971.

Dyson, George: Turing’s Cathedral. The Origin of the Digital Computer, New York, 2012.

Edwards, Paul: The closed world. Computers and the Politics of Discourse on Cold War America, Cambridge 1996.

Eley, Michael: Simulation in der Logistik: Eine Einführung in die Erstellung ereignisdiskreter Modelle unter Verwendung des Werkzeuges Plant Simulation, Berlin 2012.

Ensmenger, Nathan: The Digital Construction of Technology: Rethinking the History of Computers in Society, in: Technology and Culture, 53 (2012), issue 4, pp. 753–776.

Erickson, Paul, Judy Klein, Lorraine Daston, Rebecca Lemov, Thomas Sturm and Michael Gordin: How Reason Almost Lost Its Mind, Chicago UP 2013.

Erickson, Paul: The World the Game Theorists Made, University of Chicago Press 2015.

Eucken, Walter: Grundsätze der Wirtschaftspolitik, 6th edition, Tübingen 1990.

Experimental and Development Centre, Methodology, see Versuchsanstalt

Fildes, R. and J. Ranyard: The foundation, development and current practice of OR: An editorial introduction and overview, in: Journal of Operational Research, vol. 49, 1998, 304–306.

Fleischhack, Julia: Eine Welt im Datenrausch: Computeranlagen und Datenmengen als gesellschaftliche Herausforderung in der Bundesrepublik Deutschland (1965-1975), Zürich 2016.

Flood, Merrill: The Objectives of TIMS, in: Management Science, 2 (1956), issue 2, pp. 178–184.

Flood, Merrill: The Traveling-Salesman Problem, in: Operations Research, Vol. 4, No. 1 (Feb., 1956), pp. 61-75.

Ford, Lester, Delbert Fulkerson: Maximal flow through a network. In: Canadian J. Mathematics, 8, 1956, pp. 399-40.

Forrester, Jay: Industrial Dynamics, MIT Press 1961.

Galison, Peter: Computer Simulation and the Trading Zone, in: Gabriele Gramelsberger (ed.): From Science to Computational Science, Zürich 2011, pp. 95–130.

Gass, Saul und Carl Harris (eds.): Encyclopedia of Operations Research and Management Science, Boston 1996.

Gass, Saul: The First Linear-Programming Shoppe, in: Operations Research, 50 (2002), issue 1, pp. 61-68.

Gass, Saul und Arjang Assad: An annotated Timeline of Operations Research, New York 2005.

Geisler, Murray: A Personal History of Logistics, Bethesda 1986.

Gerovitch, Slava: From Newspeak to Cyberspeak: A History of Soviet Cybernetics, MIT Press, Cambridge 2002.

Goldstein, J.R.: Scientific Aids to Decision Making – A Perspective, in: Davies et al.: Nato Conference 1958, p. 58–62.

Gorman, Michael: Empty Railcar Distribution, in: Bruce W. Patty (ed.): Handbook of Operations Research Applications at Railroads. New York 2015, pp. 177–190.

Gramelsberger, Gabriele: Computerexperimente, Bielefeld 2010.

Gramelsberger, Gabriele (Hrsg.): From Science to Computational Science, Zürich 2011.

Greniewski, Henryk: Kybernetisch-ökonomische Modelle (Theoretische Grundlagen), in: Mathematik und Kybernetik in der Ökonomie, Internationale Tagung in Berlin im Oktober 1964, Akademie-Verlag Berlin 1965.

Haber, Samuel: Efficiency and Uplift, Chicago 1964.

Haigh, Thomas: The Chromium–Plated Tabulator: Institutionalizing an Electronic Revolution, 1954–1958, in: Annales in the History of Computing, 23 (2001), issue 4, pp. 75–104.

Haigh, Thomas, Mark Priestley and Crispin Rope: ENIAC in Action, Cambridge (Mass.) 2016.

Hanssmann, Friedrich, Unternehmensforschung: Hilfsmittel moderner Unternehmensführung, Wiesbaden 1971.

Harris, Carl: Center for Naval Analysis, in: Saul Gass and Carl Harris (eds.): Encyclopedia of Operations Research and Management Science, Boston 1996, pp. 62–64.

Heger, Hans: 100 Jahre Datenverarbeitung, vol. 1, edited by IBM, Stuttgart 1990.

Henn, Rudolf: Verfahren des Operations Research und ihre Anwendungen in der Industrie, in: Operations Research Verfahren, vol. 1, 1963, pp. 9–36.

Henn, Rudolf und Hans Künzi: Einführung in die Unternehmensforschung, 2 volumes, Berlin 1966.

Henn, Rudolf und Otto Moeschlin (eds.): Mathematical Economics and Game Theory – Essays in Honor of Oskar Morgenstern on his 75th Birthday, Berlin, 1977.

Hoffman, Karla und Manfred Padberg: Travelling Salesman Problem, in: Saul Gass and Carl Harris (eds.): Encyclopedia of Operations Research and Management Science, Boston 1996, pp. 697s.

Hofmann, Karl, Dieter Schreiter und Horst Vogel: Optimierung der Lieferbeziehungen und des Transports, Berlin 1964.

Jesiek, Brent: The Origins and Early History of Computer Engineering in the United States, in: Annals of the History of Computing, 35 (2013), issue 3, pp. 6–18.

Johnson, Stephen B.: Three Approaches to Big Technology: Operations Research, Systems Engineering, and Project Management, in: Technology and Culture, 38 (1997), issue 4, pp. 891–919.

Kantorowitsch, Leonid: Mathematical Methods of Organizing and Planning Production, in: Management Science, 6 (1960), issue 4, pp. 366–422.

Kaplan, Robert und Robin Cooper: Cost & Effect: Using Integrated Cost Systems to Drive Profitability and Performance, Boston 1998.

Kirby, M. und R. Capey: The Origins and Diffusion of Operational Research in the UK, in: The Journal of the Operational Research Society, Vol. 49, 1998, No. 4, 307–326.

Kirby, Maurice: Operational Research in War and Peace: The British Experience from the 1930s to 1970, London 2003.

Klein, Judy: Cold War, Dynamic Programming, and the Science of Economizing: Bellman Strikes Gold in Policy Space, lecture at First Annual Conference on the History of Recent Economics (HISRECO), University of Paris X – Nanterre, France, 21-23 June 2007.

Klein, Judy: “The Cold War Hot House for Modeling Strategies at the Carnegie Institute of Technology”, Institute for New Economic Thinking Working Paper Series No. 19, 68 Pages Posted: 2 Oct 2015.

Kline, Ronald: Cybernetics, Management Science, and Technology Policy: The Emergence of "Information Technology" as a Keyword, 1948–1985, in: Technology and Culture, 47 (2006), issue 3, pp. 513–535.

Knuth, Donald: The Art of Computer Programming, Band 3, Sorting and Searching, Reading 1973.

Koopmans, Tjalling (ed.): Activity Analysis of Production and Allocation, New York 1951.

Koopmans, Tjalling: Optimum Utilization of the Transportation System, in: Proceedings in the International Statistical Conference, Vol. 5, Washington D.C. 1947. (Reprint in Econometrica, vol. 17, 1949, Supplement, pp. 136–146).

Koopmans, Tjalling und Martin Beckmann: Assignment Problems and the Location of Economic Activities, in: Econometrica, Vol. 25, No. 1 (Jan., 1957), pp. 53-76.

Krige, John: American Hegemony and the Postwar Reconstruction of Science in Europe, Cambridge (Mass) 2006.

Künzi, Hans, Wilhelm Krelle und Werner Oettli: Nichtlineare Programmierung, Berlin: Springer, 1962.

Künzi, Hans, Hans Tzschach und Carl Zehnder: Numerische Methoden der mathematischen Optimierung: mit ALGOL- und FORTRAN-Programmen, Leipzig: Teubner, 1966.

Künzi, Hans, O. Müller, E. Nievergelt: Einführungskurs in die Dynamische Programmierung, Berlin 1968 (Lecture Notes in Operations Research and Mathematical Economics, vol. 6).

Künzi, Hans: Unternehmensforschung in Wissenschaft, Wirtschaft und Politik, in: Proceedings Jahrestagung der Deutschen Gesellschaft für Unternehmensforschung in Essen 1971, herausgegeben von M. Henke u.a., Physica Verlag, Würzburg 1972, pp. 3–14.

Kurbel, Karl: Enterprise Resource Planning und Supply Chain Management in der Industrie, München 2011.

Leimbach, Timo: Die Geschichte der Softwarebranche in Deutschland, München 2010.

Lück, Wolfgang: Logistik und Materialwirtschaft, Berlin 1984,

Maier, Charles: Between Taylorism and Technocracy: European ideologies and the vision of industrial productivity in the 1920s, in: Journal of Contemporary History, 5 (1970), issue 2, pp. 27–61.

Mathematik und Kybernetik in der Ökonomie, Internationale Tagung in Berlin im Oktober 1964, Proceedings, Akademie-Verlag Berlin 1965.

Mattfeld, Dirk und Richard Vahrenkamp: Logistiknetzwerke – Modelle für Standortwahl und Tourenplanung, 2. edition, Gabler Verlag, Wiesbaden 2014.

Medina, Eden: Cybernetic Revolutionaries, MIT Press 2011.

Michalewicz, Zbigniew: Genetic Algorithms, in: Saul Gass and Carl Harris (eds.): Encyclopedia of Operations Research and Management Science, Boston 1996, pp. 250–252.

Mirowski, Philip: Machine Dreams – Economics becomes a Cyborg Science, Cambridge (Mass.), Cambridge Univ. Press 2002.

Monte–Carlo–Method: Proceedings of a Symposium held June 29, 30, and July 1, 1949, in Los Angeles, US Government Printing Office, Washington D.C. 1951 (vol. 12 von National Bureau of Standards: Applied Mathematics Series).

Morgenstern, Oskar: Collaboration between Oskar Morgenstern and John von Neumann on Theory of Games, in: Journal of Economic Literature, 14 (1976), issue 3, pp. 805–816.

Müller-Merbach, Heiner: Empirische Forschung für Operations Research, in: Bernd Fleischmann et al. (eds.), Operations Research Proceedings 1981, Springer, Berlin, pp. 645-653.

Nato (ed.): NATO Conference on the Role and Evaluation of Military Exercises in Operational Research, London, England, 25 August 1964.

Neumann, von, John und Oskar Morgenstern: Theory of Games and Economic Behavior, Princeton 1944.

Nickel, Stefan, Oliver Stein, Karl–Heinz Waldmann: Operations Research, Berlin 2011.

Nievergelt, E, O. Müller, F. Schlaepfer: Praktische Studien zur Unternehmensforschung, Berlin 1970 (Ökonometrie und Unternehmensforschung, vol. 14).

Nützenadel, Alexander: Stunde der Ökonomen: Wissenschaft, Politik und Expertenkultur in der Bundesrepublik, 1949-1974, Göttingen 2005.

Nyberg, Axel: Applications of the Quadratic Assignment Problem, lecture on 15 November 2013 at Abo Universität in Turku, in the web under: http://web.abo.fi/fak/tkf/at/ose/doc/Pres_15112013/Axel%20Nyberg.pdf.

Orchard-Hays, William: History of Mathematical Programming Systems, in: Annals of the History of Computing, 6 (1984), issue 3, pp. 300–319.

Page, Thornton: First International Conference on Operations Research, Oxford, England, September 2-5, 1957, in: Operations Research, Vol. 5, No. 6 (Dec., 1957), pp. 863-871.

Potthoff, Gerhart: Linearprogrammierung im Transportwesen: Über die Anwendung mathematischer Methoden in der Wirtschaftsplanung. Beiträge aus CSSR, Ungarn und der Sowjetunion, Berlin 1961.

Ralston, Anthony und Chester Meek (eds.): Encyclopedia of Computer Science, New York 1976.

Rand, Graham: IFORS: the formative years, in: International Transactions in Operational Research, 7(2000), pp. 101–107.

Rees, Mina: The Computing Program of the Office of Naval Research, 1946–1953, in: Annals of the History of Computing, 4 (1982), issue 2, pp. 102–120.

Rid, Thomas: Rise of the Machines. A Cybernetic History, New York 2016.

Rider, Robin: Operations Research and Game Theory: Early connections, in: Roy Weintraub (ed.): Toward a History of Game Theory, London, 1992, pp. 225–240.

Rojas, Raúl und Ulf Hashagen (eds.): The first computers: history and architectures Cambridge, MIT Press 2000.

Rosenhead, Jonathan: IFORS'Operational Research Hall of Fame: Stafford Beer, in: Intl. Trans. in Op. Res. 13(2006), pp. 577–581

Rottmann, Hans: IBM/360 Modell 20: Programmieren leicht gemacht mit RPG, München 1966.

Schneeweis, Christoph: Dynamische Programmierung, in: Beckmann, Martin, Günter Menges und Reinhard Selten (eds.): Handwörterbuch der Mathematischen Wirtschaftswissenschaften, Teilband Unternehmensforschung, Wiesbaden 1979, pp. 17–45.

Schubert, D.: Untersuchung des indirekten ökonomischen Nutzeffektes der automatisierten Datenverarbeitung mittels Monte–Carlo–Simulation, in Deutsche Akademie, Mathematik und Kybernetik, 1965, pp. 111–120.

Seising, Rudolf: Cybernetics, System(s) Theory, Information Theory and Fuzzy Sets and Systems in the 1950s and 1960, in: Information Sciences, vol. 180, 2010, issue 23, pp. 4459-4476.

Shrader, Charles: History of Operations Research in the United States Army, Washington D.C. 2006.

Simon, Herbert: The New Science of Management Decision, New York 1960.

Spiess (without prename): Die Bedeutung der Rückfracht für einzelne Verkehrsmittel, in: Der Güterumschlag, Tagung und Ausstellung des VDI in Düsseldorf und Köln 1925, special issue of Zeitschrift des VDI, Berlin 1926, pp. 246–248.

Steinecke, Volker: Lineare Planungsmodelle im praktischen Einsatz, Dortmund 1973.

Teichroew, S.: Management Information Systems, in: Encyclopedia of Computer Science, edited by Anthony Ralston und Chester Meek, New York 1976, pp. 845–847.

Thomas, William: Rational Action. The Sciences of Policy in Britain and America, 1940–1960, MIT Press 2015.

Thompson, G.: IBM's RAMAC's gain wide acceptance in the first year, in: The Punched Card Data Processing Annual, vol. 8, 1959, pp. 23–25.

Thompson, Philip: Weather Prediction, in: Preston Hammer (ed.), The Computing Laboratory in University, Madison 1957, 27–42.

Thomas, William: Operations Research vis-à-vis Management at Arthur D. Little and the Massachusetts Institute of Technology in the 1950s, in: Business History Review 86 (2012), 99-122.

Traffic Practitioner, Lack of Interest, see Verkehrspraktiker

Trux, Walter: Der Einsatz quantitativer Planungsverfahren aus der Sicht des Top-Managements, in: Proceedings der neunten Jahrestagung der Deutschen Gesellschaft für Operations Research, Berlin 1981, pp. 15–24.

Vahrenkamp, Richard: Frederik Winslow Taylor – Ein Denker zwischen Manufaktur und Großindustrie, Einleitung zu Walter Volpert und Richard Vahrenkamp (eds.): F. W. Taylor: Die Grundsätze wissenschaftlicher Betriebsführung, Reprint Weinheim 1977, pp. LII – IXC. English translation under: http://www.vahrenkamp.org/files/WP21_Taylorism_EN.pdf

Vahrenkamp, Richard: Botschaften der Industriekultur – Technikdebatten und ihre Wirkungen, in: Technikgeschichte, Band 55 (1988), Nr. 2, pp. 111–123.

Vahrenkamp, Richard: Random Search in the one-dimensional Cutting Stock Problem, in: European Journal of Operational Research, 95 (1996), pp. 191–200.

Vahrenkamp, Richard: Markstudie Tourenplanungssoftware, in: Deutsche Verkehrszeitung on 17 October 2006.

Vahrenkamp, Richard: The Dream of Large–Scale Truck Transport Enterprises – Early Outsourcing Experiments in the German Democratic Republic, 1955–1980, in: Journal of Transport History, 36 (2015), issue 1, pp. 1–21.

Vahrenkamp, Richard: Die Verkehrspolitik der DDR – Konflikte zwischen dem kommunistischen Zentralisierungskonzept und betrieblichen Notwendigkeiten im LKW-Sektor, in: Zeitschrift des Forschungsverbundes SED-Staat, issue 40, 2016, pp. 3-17.

Vahrenkamp, Richard: Die erste Informationsexplosion – Die Rolle der Lochkartentechnik bei der Bürorationalisierung in Deutschland 1910 bis 1939, in: Technikgeschichte, Bd. 84, 2017, issue 3, pp. 209–242. Extended english version under: http://www.vahrenkamp.org/files/Punch_Cards_Vahrenkamp_WP1_2017.pdf

Vahrenkamp, Richard: The Computing Boom in the US Aeronautical Industry, 1945–1965, in: ICON – The Journal of the International Committee for the History of Technology, vol. 24, 2019, 127–149. Extended version under: http://www.vahrenkamp.org/files/Vahrenkamp_Computing_Boom_WP5_2018.pdf

Vahrenkamp, Richard: Nominal science without data – the artificial Cold War content of Game Theory and Operations Research, in: Real World Economic Review, vol. 88, 2019, pp. 29–51.

Verkehrspraktiker (ed.): Mangelndes Interesse der verladenden Wirtschaft an der Transportoptimierung, in: Der Verkehrspraktiker, 8 (1964), issue 3, pp. 6–7.

Versuchs- und Entwicklungsstelle des Kraftverkehrs (ed.): Methodik für die Optimierung der Transporte mit Kraftfahrzeugen, Berlin 1964.

Wäscher, Gerhard: Innerbetriebliche Standortplanung bei einfacher und mehrfacher Zielsetzung, Wiesbaden : Gabler, 1982.

Wenzel, Sigrid u.a.: Methodik zur systematischen Infomationsgewinnung für Simulationsstudien, in: Markus Rabe (ed.): Advances in Simulation for Production and Logistics Applications, Stuttgart 2008, pp. 595–604.

Weik, Martin: A Survey of Domestic Electronic Computer Systems, Report No. 971, Aberdeen 1955.

Williams, Rosalind: All That Is Solid Melts into Air – Historians of Technology in the Information Revolution, in: Technology and Culture 41 (2000), 641-68.

Woon, Marshall and Murray Geisler: Development of Dynamic Models for Program Planning, in: Tjalling Koopmans (ed.): Activity Analysis of Production and Allocation, New York, 1951, pp. 189–215.

Woon, Marshall und George Dantzig, The Programming of independent Activities, in: Koopmans 1951, 15–18.

Zimmermann, Hans–Jürgen: The founding of EURO Association of European Operational Research Societies within IFORS, in: European Journal of Operational Research 87 (1995), pp. 404–407.