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BERNARD ROY

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During the 1950s and early 1960s, as the ideas, methods, and applications of operations research (OR) spread around the world, each country tended to adapt OR to fit its professional, academic, and cultural environments. Often, there were a few dedicated persons who led the way and became recognized as the country's OR pioneers. In the case of France, such a person was Bernard Roy. After a first career as a consultant, during which he made major breakthroughs in graph theory and project scheduling, he started a second career as an academic interested in multiple criteria decision making (MCDM). Among his many achievements, he is the developer of the activity-on-node project scheduling technique and of the famous ELECTRE methods for resolving decision problems with multiple criteria. Through his research, teaching, consulting, and service to the community, he has been one of the major promoters of OR in France.

Bernard served as vice president (1974–1976) and president (1976–1978) of the Association Française pour la Cybernétique Économique et Technique (AFCET, the French OR society at that time). Bernard was president of The Federation of European OR Societies (EURO) in 1985–1986, and was awarded the 1992 EURO gold medal, the highest distinction granted by EURO.

FAMILY AND CHILDHOOD

Bernard was born on March 15, 1934 in Moulins-sur-Allier, a medium-sized town in the center of France. He is the only child of René Roy (born 1906) and Jeanne Chérasse (born 1913). Both parents completed their studies with the brevet (a diploma given to pupils at the end of the ninth grade). Bernard's maternal grandfather was a railway station manager; his paternal grandfather built and repaired millwheels. Bernard was the first member of his family to pursue an advanced education. René started his career as a bank teller. In 1934, he became an insurance agent at the Compagnie du Nord. With the help of Jeanne, he was responsible for a portfolio of clients. René took part in World War II (WWII) and, after the defeat of France, he was sent to Germany as a war prisoner. He escaped in 1943. After the war, he kept close contacts with several fellow prisoners by inviting them to yearly family gatherings. One of the ex-prisoners was the father of Bernard's future wife, Françoise. Bernard first met her during one of these gatherings.



During WWII, Moulins-sur-Allier was in the occupied part of France, but located quite close to the demarcation line. At that time, the communication between the two parts of France was highly problematic. Both Bernard's mother and aunt would cross the demarcation line to transmit mail between the two zones (sometimes even helping people to cross the line). His aunt was arrested by the Germans, but she was soon liberated following a bureaucratic error. German soldiers, realizing the error, paid frequent visits to the family's home; these visits made a very strong impression on the young Bernard. The war years were very bleak. Fortunately, Jeanne had relatives living in the countryside, so the family had access to food products that were cruelly missing, and Bernard could enjoy peaceful holidays.

In 1940, at the age of 6, Bernard started his formal education at a local school. Soon after, he began experiencing vision problems. Due to the war, it was not easy to have access to an ophthalmologist, but his parents did

manage, as best as they could. The first one consulted advised that these problems were somatic. Because things were not getting any better, several other famous specialists were consulted making various diagnoses, such as a compression of the optical nerves. It was not until 1955 that a correct diagnosis was established; Bernard was suffering from a very rare type of retina problem (atypical retinitis pigmentosa). As a result, Bernard gradually lost sight, while keeping a limited peripheral vision. Reading became more and more difficult. Writing also became problematic; after some time, hardly any one could decipher his letters. Bernard kept writing, however, by using the new Reynolds ballpoint pens that just arrived in France. He did so during elementary school (5 years in France) and through his second year of secondary school. Year after year, Jeanne helped him by reading his notes and books.

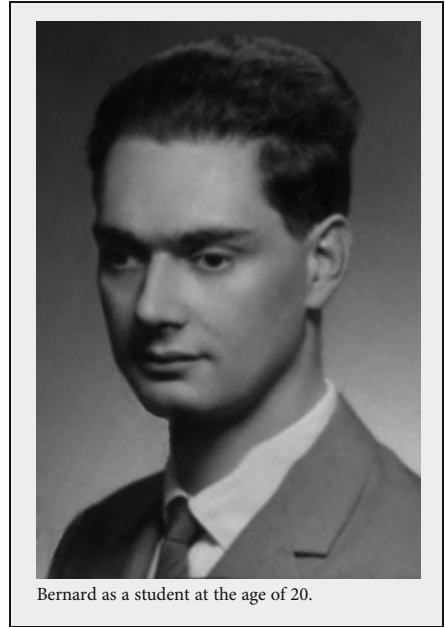
Bernard started secondary school in 1945 (consisting of 4 years of collège and 3 years of lycée). He soon abandoned writing, taking notes on a mechanical typewriter during classes. He managed to take exams using the typewriter through the two baccalauréats, which meant, at that time, the end of secondary school. Bernard's interest in mathematics was not immediate, but grew during this period. Over time, Bernard had his typewriter customized with some Greek letters added to the keyboard. He started studying English as his vision deteriorated. His father assembled for him a basic bilingual dictionary that used very large letters that Bernard could read. However, his mastering of the language was uncertain and, during the first part of his career, he published mostly in French. (He continues to favor publishing in French.) Bernard passed his second baccalauréat (in the mathématiques élémentaires section) in 1952, with the highest possible mention. At that time, even with his declining peripheral vision, Bernard could walk by himself; he rode his bicycle until the age of 22, with severe falls from time to time. But, it was obvious that his handicap would prevent him from occupying certain professions.

HIGHER STUDIES: THE ROAD TO OR

Bernard wanted to be an engineer (he had built a radio while he was in secondary school). The traditional way to become an engineer in France is not through universities, but through the distinct system of Grandes Écoles in which students are selected on the basis of a competitive exam

that could only be taken after 2 years of Classes Préparatoires. Bernard went to Paris for his first year of Classes Préparatoires at the Lycée Chaptal. His results were so high that he was admitted for the second year to one of the most prestigious Classes Préparatoires at the Lycée Louis-le-Grand, usually the first step to the École Polytechnique or the École Normale Supérieure. In class, Bernard was using his relatively quiet typewriter to take notes. But, his physics teacher thought that the noise was intolerable and did not allow him to use the typewriter. Thus, Bernard, not being able to take

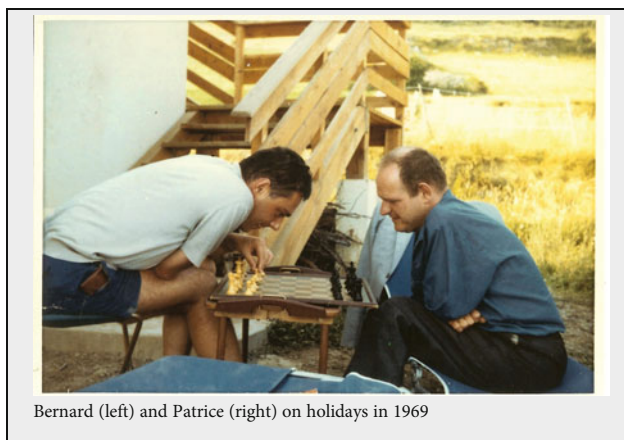
notes and rather shaken by this decision, left the Lycée Louis-Le-Grand and the Classes Préparatoires system in October 1953. Thus ended his dream of entering the École Normale Supérieure. He immediately decided to enroll in the Université de Paris and study for a degree in mathematics. At that time, the Licence de Mathématiques meant obtaining three certificates: this usually took 3 years (the Licence had to be preceded by a general mathematics certificate that Bernard had passed while he was at the Lycée Chaptal). In the academic year 1953–1954, Bernard completed two of the three certificates (calculus and probability). He was taught by some great mathematicians who became famous: Laurent Schwartz (founder of the theory of distributions and a member of the Bourbaki group), Jacques-Louis Lions (one of the major promoters of applied mathematics in France, a president of the International Mathematical Union, and father of the future Fields medal laureate Pierre-Louis Lions), Gustave Choquet (developer of the theory of capacities), and Robert Fortet (founder of the most important French research group in the theory of probability). Bernard got even with the École Normale Supérieure—he completed his calculus certificate with the highest possible mention, ending up tied with a student from that school.



Bernard as a student at the age of 20.

During the 1953–1954 academic year at Université de Paris, Bernard met Patrice Bertier, a fellow student in mathematics. Patrice suffered poliomyelitis during his youth and was using a wheel chair. He and Bernard became great friends. They spent the year studying together and helping each other. Patrice completed his Licence in June 1954 having passed the three certificates. His plan was to take courses at the Institut d'Études Politiques (IEP) in the next academic year. IEP was a relatively special Grande École, mainly oriented toward economics and political science; it was the usual first step to the highest positions in the French civil service. At that time, the teaching of economics and political science had little to do with mathematical economics and, for someone holding a degree in mathematics, enrolling in IEP was extremely uncommon. But, Patrice was attracted to economics. He persuaded Bernard to join him in this adventure. The only problem was that Bernard had not completed his Licence: he had to obtain his third certificate. Bernard then decided to study for his missing certificate during summer. He finally obtained this certificate (in rational mechanics) in September 1954, thus completing his 3 years of Licence in only 1 year.

Both Bernard and Patrice joined IEP in October 1954. As this was really unusual—mathematics students at IEP—they also enrolled in the Institut de Statistique de l'Université de Paris (ISUP), an interfaculty department that granted diplomas in statistics and probability. IEP was located at rue Saint-Guillaume, west of the Latin Quarter, while ISUP was located at rue Pierre-et-Marie-Curie, near the Jardin du Luxembourg, south of the Latin Quarter. During the years 1954 and 1955, people walking on



Bernard (left) and Patrice (right) on holidays in 1969

the Boulevard Saint-Michel would often observe a strange event: Bernard, half blind, pushing the wheel chair of Patrice, as they went back and forth between ISUP and IEP. At ISUP, Bernard had several remarkable teachers:

Georges Darmois, Georges Morlat, Dickran Indjoudjian, Germain Kreweras, René Roy. ISUP was then one of the rare places in France in which applied probability and statistics were taught to highly trained mathematics students. Here, Bernard discovered mathematical statistics and econometrics; applied statistics was not forgotten, although all computations had to be done on electric non-programmable calculators. At IEP he attended the courses of Alfred Sauvy (an economist and demographer who, in 1952, first used the expression *Tiers Monde* [Third World]), Jean Fourastié (an economist who coined the expression *Les Trente Glorieuses* [The Glorious Thirty]—the 30 years from 1945 to 1975), Paul Delouvrier (an economist and urban planner), and André Siegfried (a sociologist specialized in electoral studies). This unique combination of mathematics and economics aroused the interest of Bernard for the application of mathematics to the real world.

The years 1954–1955 were exciting times for Bernard. Several people—Georges-Théodule Guilbaud, Germain Kreweras, Jean Abadie, Jean Ville, Pierre Bouzitat, Marc Barbut, Michel Rosensthiel, Jean Mothes, Claude Berge—began giving unofficial lectures and seminars on OR; OR was not part of any course in France. Bernard especially remembers the lectures of Guilbaud. They were attended by huge crowds in the Amphithéâtre Hermite of the prestigious Institut Henri Poincaré. Bernard had found his way to applying mathematics in the real world. He wanted to do OR. The emerging French OR community was beginning to organize itself and, in 1956, the Société Française de Recherche Opérationnelle (SOFRO) was established. [In 1964, SOFRO became AFIRO (Association Française d'Informatique et de Recherche Opérationnelle), after a merger with a society of computer scientists; in 1968, it became AFCET (Association Française pour la Cybernétique Économique et Technique), after a merger with a society of cyberneticians; and in 1998, AFCET split apart with the French OR society becoming ROADEF (Société Française de Recherche Opérationnelle et d'Aide à la Décision) (Roy 2006)].

These were years of intense activity for Bernard. Besides the courses at IEP and ISUP, he also obtained additional certificates in mathematics (mathematical methods of physics, algebra, and number theory). He completed his master's degree at ISUP in 1957 with his first research in OR: a master's thesis on the newsboy problem presented as the baker's problem (*problème du boulanger*) (Roy 1957). He decided to start a Ph.D. on the same subject, but soon abandoned it in favor of graph theory.

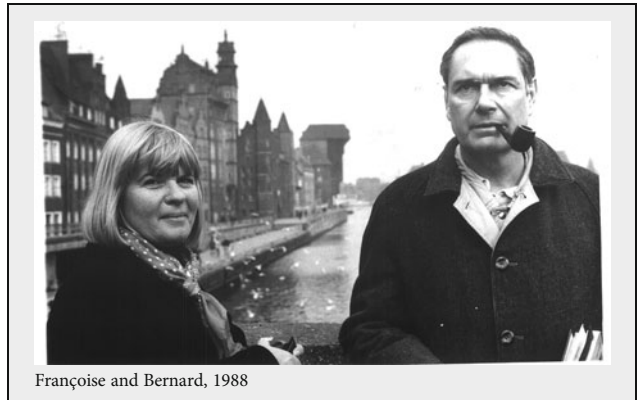
In July 1956, Robert Fortet managed to obtain positions as junior researchers for both Bernard and Patrice at the Centre National de la Recherche Scientifique (CNRS, the national research agency, created in 1939, to promote fundamental research in France). The jobs paid little but offered immense freedom. As CNRS did not have an office at that time, Bernard and Patrice were also recruited as interns at Électricité de France (EDF, the newly nationalized electricity company) under the supervision of Marcel Boiteux, who was in charge of EDF's Service des Études Économiques Générales (he later became CEO of EDF). Bernard completed his master's thesis for ISUP during this period; he benefited from the advice of Marcel Boiteux on how to write a paper. At that time, EDF had no computing facilities. Small linear programming (LP) models were used to plan production between thermal and hydraulic plants. Bernard and Patrice were still interns at that time and, since the problems involved strategic elements, they did not have full access to the data and results; their main role was to devise the general structure of the LP models. These problems, although small sized (around 50 variables), were still too large to be efficiently solved by hand. Marcel Boiteux and Pierre Massé (the vice-CEO of EDF) were sending these problems by ordinary mail to George Dantzig at the RAND Corporation in Santa Monica, California, with the results also returned by mail. At that time, processing time did not reduce to computation time.

CONSULTANT AT SEMA

Bernard married Françoise Jolivet in July 1957. They had six children, Sylvie (1958†), Laurence (1961), Isabelle (1964), Solange (1966), Patrice (1968), and Philippe (1970†), and nine grandchildren. The meager salary from the CNRS was not adequate to support the young couple. Bernard left CNRS when he was recruited by a newly created OR consulting company, the Société d'Études Pratiques de Recherche Opérationnelle (SEPRO). Meanwhile, the Société de Mathématiques Appliquées (SMA) was created as a joint venture between the Banque de Paris et des Pays-Bas (more commonly known as Paribas) and an independent consulting company led by Marcel Loichot. The aim of SMA was to be a consulting company that would promote the use of management science (MS) in French companies. Jacques Lesourne was appointed as CEO. Bernard left SEPRO to join SMA as a consultant in October 1957, together with Patrice Bertier. SMA quickly became SEMA (Société d'Économie et de Mathématiques

Appliquées). After having created several subsidiaries in Europe, SEMA became SEMA (Metra International).

SEMA started with around 10 employees and almost no contracts. Bernard's first task, with Patrice, was to translate into French several chapters of the OR text written by Churchman et al. (1957). They also put the final touches to the book by Lesourne (1958), one of the first OR books written and published in French.



Françoise and Bernard, 1988

Contracts began to arrive in 1958 and Bernard started to work on applied OR problems, mainly from the private sector. He worked on a variety of problems that involved many ideas and techniques: probability and queueing theory (reducing the waiting time at a ferry), data analysis (choosing the name of a new brand of cigarettes), transportation studies (developing a forecasting model for transportation planning), cutting stock (designing cardboard boxes), location (choosing sites for plants), and finance (optimizing cash management). Many of these applications were later published in *METRA*, the future academic journal sponsored by SEMA. Bernard's most important works were concerned with project scheduling and related graph theory problems.

SEMA was growing steadily during this time. In 1962, it acquired a Control Data computer (CDC 6600) for which several LP and integer linear programming (ILP) codes were developed that enabled larger problems to be solved. Before that, all computations were performed by a bureau de calcul employing many persons working on electric calculators.

In between contracts, Bernard worked on his Ph.D. dissertation in graph theory and its application to project scheduling (together with a minor dissertation on abstract algebra). He received his Ph.D. in 1961 (dissertation on "Cheminement et connexité dans les graphes: Application aux problèmes d'ordonnancement" [Roy 1961])) from the

Université de Paris, under the supervision of Claude Berge [the author of one of the first books on graph theory (Berge 1958)]. That same year, Bernard was offered a position at the Université de Paris in mathematics. OR, at that time, was not part of the mathematics curriculum and the teaching of mathematics was slanted toward pure mathematics—this period was highly influenced by the Bourbaki group. As accepting the position meant returning to pure mathematics, Bernard declined the offer. Taking advantage of SEMA's policy that encouraged its consultants to teach, Bernard did become involved in teaching OR courses at the Centre Inter-armées de Recherche Opérationnelle (a permanent education program in OR for French officers) and, with Claude Berge, taught seminars on graph theory and combinatorial problems.

In 1962, Jacques Lesourne created within SEMA a scientific group called Direction Scientifique, with the objective of helping consultants in applying new scientific and computational techniques. Bernard joined this group as a consultant of consultants. He became its director in 1964. For many years, this high-powered, multidisciplinary group was the site of intense activity; its members included Raphaël Benayoun, Patrice Bertier, Éric Jacquet-Lagrèze, Hubert Le Boulanger, Benjamin Matalon, Jean de Montgolfier, Hervé Raynaud, and Gilbert Sussmann. At the same time, SEMA launched a quarterly journal called *METRA* to popularize the new techniques it promoted (they included OR techniques, but also covered every aspect of MS). Bernard was appointed its editor-in-chief and remained so until the journal ceased publication in 1977. *METRA* published papers written by SEMA consultants and from its European subsidiaries in four languages (French, Spanish, Italian, and English). It is remarkable that the editorial policy of *METRA* was to promote the techniques developed at SEMA. Its methodological advances could appear in the journal after observing a publication lag of about 2 years which SEMA required to protect its competitive advantage.

Although edited by a commercial company, *METRA* had a standard academic way to process papers and had a scientific editorial board that included academics (most notably Stafford Beer and Paul Gillis). In those times, few French libraries had subscriptions to *Management Science*, *Journal of the Operational Research Society*, or *Operations Research*. Thus, *METRA*, together with *RIRO* [*Revue d'Informatique et de Recherche Opérationnelle*, the newly created journal of AFIRO that would later become *RAIRO* (*Revue d'Automatique, d'Informatique et de*

Recherche Opérationnelle)] played an important part in the diffusion of OR techniques in France.

Consulting, therefore, greatly influenced Bernard's view of OR techniques and applications. Most often, the lack of appropriate software, the paucity or poor quality of data, the softness of some constraints, and the presence of multiple conflicting objectives made the quest for an optimal solution illusory. A good solution that could not be proved optimal was often a major breakthrough in practice. These real-world concerns greatly influenced Bernard's approach to his future research.

PROJECT SCHEDULING AND GRAPH THEORY

One of the most famous contributions of Bernard is in the field of project scheduling. In 1958, when working at SEMA, he was faced with the problem of scheduling the construction of new buildings for the headquarters of a large company in Paris. Managing this project, involving several hundreds of tasks and more than one thousand constraints, required a specific methodology. At this occasion, Bernard developed a method called MPM (*Méthode des Potentiels Metra*). MPM was based on what is now known as the activity-on-node (AON) formulation (Roy 1959a, 1962). While its theoretical foundations were being established (in terms of existence and optimality of schedules), this method was applied successfully to several other scheduling problems (production of crankshafts at Mavilor Motors, design of an appropriate cycle for the new Tracoba house-building process). These applications involved potential constraints (i.e., constraint of the form $t_j - t_i \geq a_{ij}$, where t_j is the starting time of task j and a_{ij} is the minimum time between the start of tasks i and j) and more difficult constraints such as disjunctive or cumulative constraints (disjunctive constraints impose that two tasks do not occur simultaneously, and cumulative constraints require that simultaneous tasks do not consume more than a given amount of resources; this typology of constraints was developed by Bernard). MPM was one of the first computer-based software systems for project scheduling: CONCORD (CONception et Coordination de l'ORDonnancement) (Roy and Dibon 1966). [The AON approach was proposed independently in the U.S. under the name Precedence Diagramming Method by Fondahl (1961).] The existence of a large

number of difficult constraints, in the context of scheduling the equipment of the steamship liner *France* (the largest in the world in 1960), eventually led to the development of another technique, *description segmentée*, designed to quickly spot incompatible constraints in a system of linear inequalities (Roy 1963; Roy and Simonnard 1961).

Simultaneously and independently, methods like PERT or CPM, based on an activity-on-arc (AOA) formulation were developed in the U.S. in the late 1950s (at DuPont de Nemours, RAND Corporation, and the U.S. Navy for the deployment of the POLARIS missile). It is now widely acknowledged that the AON formulation is superior to the AOA formulation, since it is more systematic, without requiring modeling tricks such as dummy arcs, and its ability to readily handle changes or additions to constraints.

Bernard also obtained results on more theoretical aspects of graph theory, related, for example, to optimal paths, connectivity, transitivity, and chromaticity (Roy 1958, 1959b, 1967, 1969b). As discussed by Hansen and de Werra (2002), some of these pioneering results, obtained over 50 years ago, are still the basis of currently published results.

Also well known is the so-called Roy–Warshall’s algorithm that computes the transitive closure of a digraph (Roy 1959b; Warshall 1962). This algorithm was discovered independently by Bernard in 1959 and Stephen Warshall in 1962. In the subfield of network flows, the algorithm to determine a minimum cost flow by successive shortest paths is known as Busacker and Gowen’s (1961) algorithm in the U.S. and as Roy’s algorithm in Europe. Bernard independently developed this approach in the early 1960s and presented it at several conferences (Roy 1970).

Bernard is the author of a remarkable two-volume, 1300-page textbook on graph theory (Roy 1969c, 1970). Even if it is now outdated on some points, it includes an original treatment on many topics that should be of interest to anyone in this field. Bernard organized two summer schools on graph theory and discrete mathematics. The first one, co-organized with Frank Harary, took place in 1966 in Italy with more than 100 participants. The second one was in Versailles, France, in 1974. Both schools gathered most of the major names in the field of graph theory and combinatorial optimization. The proceedings of the second

school were published in Roy (1975b). With Patrice Bertier, Bernard was also among the pioneers who developed and formalized branch and bound procedures in the mid-1960s (Bertier and Roy 1965; Roy 1969a).

ELECTRE AND MULTIPLE CRITERIA DECISION AIDING (MCDA)

Bernard's research on multiple criteria decision problems was motivated by real-world problems encountered by SEMA clients. This led to the development of the first ELECTRE method, ELECTRE I (Roy 1968), for solving such problems. A media planning problem led to the development of ELECTRE II (Roy and Bertier 1973). At that time (mid-1960s), Bernard was unaware of the parallel developments in the U.S. by Howard Raiffa, Ralph Keeney, and many others. Bernard accepted the invitation of George Dantzig to organize two sessions on MCDM for the 1970 Mathematical Programming Symposium to be held in The Hague (Roy 1971). These sessions were among the first of their kind to be given at such conferences. During this time, Bernard, working early in the mornings, completed his two-volume exposition on graph theory and its applications (Roy 1969c, 1970).

ELECTRE METHODS: AN EXPOSITION

ELECTRE (Élimination et Choix TRaduisant la Réalité) methods were first developed in the mid-1960s to answer real-world problems brought to Bernard by SEMA consultants, such as the selection of research projects or of investment opportunities. SEMA had developed a technique, called MARSAN (Méthode d'Analyse et de Recherche pour la Sélection des Activités Nouvelles), that was designed to help firms in selecting new activities. To do so, activities were evaluated on a series of 48 dimensions (the word criterion was not used then). They included quantitative as well as qualitative dimensions. Qualitative dimensions were translated on a numeric scale more or less arbitrarily. A weighted sum of all these numbers was computed to measure the attractiveness of these new activities.

It soon became clear that the use of a weighted sum allowed compensation effects that were not desirable: small advantages on

several dimensions could compensate for major weaknesses on some others, which was not felt to be desirable. Moreover, the transformation of qualitative dimensions into numbers was playing an important part in the final result.

Bernard devised a method that would deal both with qualitative dimensions without the need for transforming them into quantitative dimensions and that would not tolerate compensation effects that were felt undesirable. This was the birth of ELECTRE I (Benayoun et al. 1966; Roy 1968). Basically, in ELECTRE I, alternatives are compared in pairs using the following reasoning: Alternative *a* will be declared at least as good as alternative *b* if (1) the proposition is supported by a sufficient majority of dimensions (concordance condition), and (2) among the dimensions opposing the proposition, there is none on which the opposition is too strong (non-discordance condition).

Such an at-least-as-good-as relation (soon called an outranking relation) can be built on the basis of purely ordinal considerations. The non-discordance condition prevents undesirable compensation effects from occurring. The application of the concordance condition leads to assigning weights to each dimension. To decide if a majority of dimensions is sufficiently important, the sum of the weights is compared to a threshold called the concordance threshold (note that these weights are quite different from the weights used in a weighted sum; they are never multiplied with scores and are, therefore, independent from the scale used to measure scores). Similarly, the strength of the opposition of dimensions is computed using a veto threshold.

A specific feature of this relation is that it does not have to be transitive (even in its asymmetric part, because of Condorcet-like effects) or complete (some alternatives may remain incomparable). Therefore, deriving a prescription on this basis is not an easy task and calls for the application of specific techniques, called exploitation techniques. They differ on the type of recommendation that is looked for. ELECTRE I has been designed in a choice problem formulation—it aims at recommending a subset of alternatives (as small as possible) that is likely to contain the best alternatives. Technically, viewing the outranking relation on the set of alternatives as a graph, Bernard suggested using the kernel (an independent and dominating subset) of this graph.

ELECTRE II (Roy and Bertier 1973) is a variant of ELECTRE I that is designed to rank order alternatives. It uses two outranking relations instead of one. The ranking is not necessarily complete: it preserves incomparability between alternatives that appear difficult to compare. ELECTRE III (Roy 1978) is a far-reaching generalization of ELECTRE II that uses a fuzzy outranking relation instead of two crisp ones. Furthermore, it refines the preference modeling on each dimension with the introduction of thresholds preventing small differences between scores from being interpreted as a definite advantage. Such thresholds were introduced in a new version of ELECTRE I, called ELECTRE IS. ELECTRE IV (Roy and Hugonnard 1982) is a variant of ELECTRE III designed to deal with situations in which weights are difficult to elicit, given the diversity of opinions. ELECTRE TRI (Roy and Bouyssou 1993) is designed to deal with a sorting problem formulation in which each alternative is assigned to a category pre-defined by norms which, for example, separate good and bad credit files.

All these methods were developed to deal with specific real-world problems. ELECTRE methods have been applied to a large variety of problems in many countries (Figueira et al. 2005; Roy 1991; Roy and Bouyssou 1993).

MCDA: AN ORIGINAL PERSPECTIVE ON OR

Bernard's concept of OR was influenced by two major themes: the starting of his career as a consultant and his later work in MCDM. Their synergistic interaction led him to develop a decision-aiding methodology that is original and rather non-standard in the OR profession (Roy 1975a, 1977, 1985, 1990, 1993). He noticed that the application of OR models and methods were characterized by the adherence to three main assumptions:

1. The quest for rationality implies the use of a unique criterion that should be optimized.
2. Qualitative information and ambiguous data should be avoided as much as possible.
3. Science aims at describing a reality that is mainly independent from the observer. Reference to this outside reality is central to the validation of a scientific model.

Bernard soon became rather skeptical about these three assumptions and proposed a decision-aiding methodology that would dispense with them (Roy 1981).

Indeed, Bernard quickly acknowledged the fact that in many real-world problems, several actors are involved. These several stakeholders have different opinions. Quite often, their opinions are not always completely structured. Also, there may be no real decision maker. Moreover, what is feasible or what is not feasible is often fuzzy (Roy 1988). This undermines the first assumption and calls for the use of multiple criteria. This does not mean that optimizing is useless, but simply that optimality within a model does not guarantee an acceptable solution, let alone an optimal one, in the real world.

Real-world situations abound with qualitative information. Contrary to the second assumption, information is often uncertain, imprecise, and ill-determined. Trying, by all possible means, to convert all that is qualitative into quantitative information is a difficult task and often leads to a result that is seldom meaningful. Spending time to obtain information of better quality is often an inappropriate use of resources and may lead to instrumental bias (recall the drunkard looking for his keys under a street lamp without really knowing where he lost them). In all real-world problems, irreducible uncertainty, imprecision, and inaccurate determination will remain (Roy 1989). Hence, we should reconcile ourselves that we must deal with the available qualitative information, using techniques that allow robust conclusions to result (Roy 1998).

Decision aiding inevitably means working with preferences. When facing a complex problem, it is rare to have the actor(s)'s preferences clearly stated and completely well structured (Roy and Vincke 1984). The analyst must question the actor(s) and, thus, contributes to the shaping of the preferences, as well as describing them. A clear violation of the third assumption. This learning process, which is often a creation process, is an inevitable part of applying OR models (Roy 1987).

Over the years, Bernard has proposed a complete decision-aiding methodology that does not rely on the above three assumptions (Roy 1985; Roy and Bouyssou 1993). This explains why Bernard prefers to speak of MCDA instead of MCDM.

Bernard's most recent research deals with robustness in decision aiding. In many decision contexts, model parameters are often defined approximately due to uncertainty, imprecision, or ill-determination (Roy 1998). Rather than looking for optimal solutions, it is then more appropriate to look for robust solutions that are resisting to vague approximations and areas of ignorance, that is, which behave well for all, or at least most, plausible values of the parameters. Such a perspective, often well received by practitioners, gives rise to many challenging theoretical questions. Bernard's approach to robustness is discussed in Roy (2010).

PROFESSORSHIP

In the late 1960s, following the May 1968 events in France leading to a 1-month general strike, Bernard started wondering about his future career. Jacques Lesourne had announced that he would soon leave SEMA. During this time, Bernard was asked to give a doctoral course on OR at the newly created Université Paris-Dauphine (this experimental university was created in 1968 and occupied the former NATO headquarters in Paris). In 1971, he was appointed associate professor in mathematics (later joining the computer science department). The following year, he was made full professor. He



(Left to right) Daniel Vanderpooten, Bernard Roy, and Denis Bouyssou (2007)

kept his position at SEMA until 1974, progressively reducing his involvement, as SEMA reduced its OR activities; he remained associated with SEMA as a scientific advisor until 1979. One of Bernard's early academic duties was to reshape the MS curriculum within the management program. In 1974, Bernard created a research group called LAMSADE (Laboratoire d'Analyse et Modélisation de Systèmes pour l'Aide à la Décision) which became affiliated with CNRS in 1976. LAMSADE was one of the few research groups in France oriented toward applied OR. Over the years, as LAMSADE kept growing, it expanded its base of interest to include research topics in computer science.

Bernard made sure that the Dauphine OR curriculum included a doctoral program, *Méthodes Scientifiques de Gestion*, and thus, through the years, he began his supervision of over 50 doctoral students (both authors of this text are his former doctoral students). His research at LAMSADE became more and more oriented toward MCDM, or rather MCDA.

Although Bernard devoted much energy to the development of LAMSADE and served as its director until 1999, he also undertook several important responsibilities within Université Paris Dauphine, including the directorship of a doctoral school. In addition, in 1980, Bernard became scientific advisor of RATP (Régie Autonome des Transports Parisiens; the company that operates all public transports in the Paris region).

Bernard is the author of more than 80 papers in refereed journals and nearly 50 papers in contributed volumes. A selected list of Bernard's publications is available from LAMSADE (2009).

Bernard retired in 2001 with the title of professor emeritus. A Festschrift honoring him was published on the occasion of his retirement (Bouyssou et al. 2002). He remains quite engaged in his scientific and consulting activities.

HONORS AND AWARDS

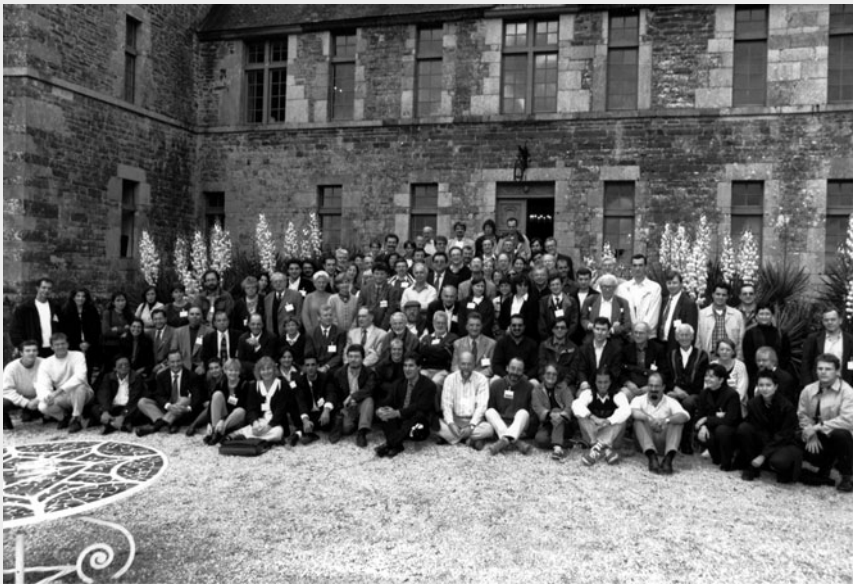
Bernard has received six honorary doctoral degrees (Vrije Universiteit Brussels, Belgium, 1978; Université de Liège, Belgium, 1978; Université de Fribourg, Switzerland, 1982; Poznan University of Technology, Poland, 1992; Université Laval, Canada, 1998; Technical University of Crete, Greece, 2002). He received the 1992 EURO gold

medal, the highest distinction granted by EURO. He holds the gold medal from the MCDM International Society, as well as the Hermès de la Recherche Prix from the Université Laval, Québec, Canada.

Bernard served as vice-president (1974–1976) and president (1976–1978) of AFCET. He was the president of EURO (1985–1986), after having served on the executive committee for several years. In 1975, he founded one of the most active and long-lasting working groups in OR, the EURO working group on MCDA.

THE EURO WORKING GROUP: MULTIPLE CRITERIA DECISION AIDING

EURO is a federation of the national European OR societies. The first EURO conference was held in Brussels in 1975. Bernard created the EURO working group on multiple criteria decision aiding (MCDA). The group, which usually meets twice a year, aims to promote original research on MCDA in Europe. The meetings of the group are not conferences. They are designed to foster discussions and exchanges. The group has around 350 members, from about 30 countries, and meetings usually gather between 50 and 100 persons. The success of the group is attested by the fact that most texts on MCDM now speak of a European school of MCDA (Roy and Vanderpooten 1996). The 69th meeting took place in Brussels, Belgium, April 2–3, 2009. More details on this working group can be found at <http://www.inescr.pt/~ewgmcda/index.html> (viewed December 24, 2009).



50th anniversary meeting of the MCDA working group convened at Château de Cerisy-La-Salle in 1999. Bernard is in the second row in the middle (wearing the lighter jacket in this row).

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