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Advanced Studies in Multi-Criteria Decision Making

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Foreword

Multiple criteria decision making (MCDM) is an effective approach to structuring a complex problem and exploring meaningful courses of actions to converge to good solutions that balance various concerns of decision makers. The need to do this is becoming more crucial as the challenges the planet and the societies are facing get more complex and the consequences get more grave. There seems to be an agreement among scientists that climate change has passed certain thresholds and some of the potential disasterous effects to the planet are now irreversible. In addition to climate change, racism, access to healthcare, lack of education, unemployment, immigration, and poverty are some of the major problems faced by masses in the twenty-first century. Many of those who are in positions to make changes, however, seem to overlook these major problems. We seem to be far from the necessary vision and collaboration to start making progress on these urgent issues. The efforts of many nongovernmental organizations to attract societies' attention to some of these problems are commendable but not sufficient to reverse the negative effects. This is where I believe MCDM scholars can make a difference. Studying such complex problems that have the potential to ruin many lives of future generations may make a positive impact. We have the capability of structuring, exploring, and demonstrating the consequences of various decisions (especially the business-as-usual scenarios). Disseminating these results not only in scholarly publications but also in mass media can increase the awarenesses of the societies and may help initiate major changes in the right direction.

I personally know the editors and many of the authors of this book. They have been making important methodological and practical contributions to MCDM. I have served the International Society on MCDM for many years in different capacities including as president of the society for 4 years. During my tenure at these positions, I have known and

collaborated with many MCDM scholars including the editors and authors of this book. Many of the works published in this book were presented at the 24th International Conference on MCDM held in Ottawa, Canada in July 2017. Sarah Ben Amor, the lead editor of this book, and her colleagues organized the conference. The theme of the conference was "Creating a Sustainable Society," fitting well with the concerns I mentioned above. The conference was memorable both scientifically and socially. There were plenary talks on climate change and sustainable healthcare, as well as regular talks on complex societal problems. This book is a good reflection of the rich content of the conference and it is an important step in the direction our field should grow in order to make important contributions to complex environmental and socio-economical problems. Some of the topics the book covers are major trends in today's world from an MCDM perspective, and applications in the areas of healthcare, sustainable planning, telecommunication, agriculture, and planning under uncerainty.

The MCDM community is large and very international; The International Society on MCDM currently has over 2700 members from about 100 different countries. Conferences once every two years typically attract 300–500 scholars from about 40 different countries. The MCDM summer schools held every two years bring some of the best instructors to interact with about 50 PhD students coming from all over the world. I would like to see young researchers follow the lead of this book and collaborate more with experienced researchers as well as those from different disciplines to address the challenging problems that are threatening our planet and societies. After all, MCDM scholars are among the best equipped researchers to make differences in these urgent issues.

Murat Köksalan

President, International Society on MCDM, 2015–2019

Ann Arbor, Michigan

Preface

The book *Advanced Studies in Multi-Criteria Decision Making* presents a state-of-the-art, international collection of contributions about recent Multi-Criteria Decision Aiding/Making (MCDA/M) developments. Given that Decision Sciences are recognized today as indispensable for confronting the major societal challenges in science and technology, the book addresses a set of topics in which MCDA/M is crucial in today's digital reality. Without the proper MCDA/M tools, the necessary developments and innovative research would be impeded, making it harder to answer growing global problems in areas such as climate change, energy and transportation, healthcare and social sustainability—with all their diverse repercussions within the national and local contexts.

Most of the studies in this volume are developed within the international cooperation framework for R&DI projects. The contributing authors come from many different countries, and the topics of the chapters originated in MCDM-2017 (http://sites.telfer.uottawa.ca/mcdm2017/), the international conference of the prestigious *International Society on Multiple Criteria Decision Making* that brought many of them together. The conference was held in Ottawa (Ontario, Canada) in July 2017, which was also Canada's 150th anniversary.

In Chapter 1, H. Wallenius and J. Wallenius provide an overview of the mega-trends that are transforming the world, with a focus on technology transformations that are of interest from an MCDM perspective. They discuss the role that MCDM could play in these mega-trends, as well as how mega-trends have been changing MCDM.

In Chapter 2, Clímaco and Craveirinha highlight how the rapid evolution of new telecommunication technologies and services has given rise to a growing interest in applying multi-criteria evaluation approaches in a wide variety of decision-making processes involved in network planning and design. The authors provide an overview of contributions, critical

evolutions, challenges and future trends concerning the applications of MCDA/M in telecommunication network planning and design.

In Chapter 3, Norese introduces SISTI, a methodological multicriteria modelling approach to structure a new and complex problem and to elaborate and validate a new model when decision makers do not exist, cannot participate or do not want to be involved in the decision-aiding process. This approach is especially effective for new practitioners to help them understand what a "good" model is and how the robustness of their conclusions can be improved.

In Chapter 4, Polyashuk focuses on multiple-criteria models for decision-making situations with a complex set of criteria. More specifically, she explores different ways to treat quantitative (tangible) and qualitative (intangible) criteria in a model aiming at approximating decision maker's preferences in an efficient and unbiased manner.

In Chapter 5, Dopazo and Martínez-Cespedes present methods and algorithms for smart-city rankings. They propose a two-stage approach to address the group-ranking problem in the smart city context. Their approach is based on deriving the priority vectors of cities from outranking matrices that collect relevant information from input data. The application of the proposed methods is illustrated using the data provided by the IESE Cities in the Motion Index 2016 (CIMI 2016) report. Their approach provides a theoretical framework for studying the problem, efficient computational methods to solve it and some performance measures.

In Chapter 6, Aguirre and Manyoma examine agricultural supply-chains prioritization for the development of areas affected by the military conflict in Colombia. Prioritization is necessary in national and international organizations to effectively direct their resources toward the development of the incipient agro-chains of the region. Using MCDA, the authors provide a ranking of the agro-chains that best represent this region of the country.

In Chapter 7, Miranda, Nagy and Casquilho examine decision-making and robust optimization for medicines shortages in pharmaceutical supply chains. The main topics of the COST Action "Medicines Shortages" (CA15105) are introduced, and they discuss how MCDM tools can be used to address the suppliers-selection problem and to curb shortages. A case-study that involves a supplier bid is analyzed using four different MCDM methods and resulting in the selection of one of the bidder-supplier companies.

In Chapter 8, Brison, Delbaere, and Pirlot adapted spatial decision models to address the following question: is it possible to rank chocolates with different degrees of fat bloom (i.e., a white-grayish layer or white spots on their surface due to fat recrystallization) without an expert panel? More specifically, models that were initially developed to help decision-makers express their preferences over maps representing the state of a given territory at different times were applied to rank chocolates.

In Chapter 9, Skulimowski proposes a model in which anticipatory decision-making principles are integrated with multicriteria sustainable planning. The model is applied on a real-life case-study to analyze the planning of the future operation of an innovative digital knowledge platform with respect to multiple criteria related to financial sustainability, technological excellence and social benefits. This platform has been developed within an ongoing EU Horizon-2020 research project (cf. www.moving-project.eu).

In Chapter 10, Kandakoglu and Ben Amor propose a robust multiple-criteria approach to select a Course Of Action (COA) in a military operation-planning process. The approach is based on the SMAA-PROMETHEE method that performs Monte-Carlo simulations and runs PROMETHEE to investigate the robustness of COA rankings when input parameters are uncertain or incomplete. The main advantage of this approach is its ability to articulate to the commander why one COA is preferable to another by exploring the input-parameter space that assigns a given COA to a certain rank.

In Chapter 11, Kilic and Kabak analyze the relationship between human development and competitiveness using the combined approach of Data Envelopment Analysis and cluster analysis. Using this approach, 56 countries are evaluated and ranked for the years 2010–2017 based on the data of the Global Competitiveness Index and Human Development Index.

With these contributions, the book presents an updated picture of the landscape of Decision Sciences, their current research topics, their interaction with other sciences, their useful collaborations with industry and services, as well as recent or ongoing international challenges.

The chapters of this volume, with relevant contributions about the application of Decision Sciences and their tools, are of interest to a broad spectrum of readers who wish to gain a fresh insight into the MCDA/M state-of-the-art, including decision-makers, managers, researchers, and MSc/PhD students.

At last, we would like to express our appreciation and gratitude to all the authors for their quality contributions, as well as we very much thank the reviewers too for their time and valuable inputs.

Sarah Ben Amor

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Editors

Sarah Ben Amor holds an MSc and a PhD in Business Administration, specializing in operations and decision support. Her research is focused on multi-criteria decision making. It looks mainly at uncertainty modeling, information imperfections, and how they are treated in multi-criteria decision analysis. Her expertise in model building and uncertainties associated with multi-criteria analysis has benefited various R&D projects for Defence R&D Canada–Valcartier, particularly with regard to risk analysis. She also has numerous applications in different fields such as finance, innovation, and healthcare systems.

Adiel Teixeira de Almeida is Professor of Management Engineering at Universidade Federal de Pernambuco and founding coordinator of the Center for Decision Systems and Information Development (CDSID). He holds a PhD in management engineering from the University of Birmingham, UK. His main interests are in decision making related to multiple objectives and group decision problems, which includes methodological issues and applications. Also, he has been working as a consultant and with R&D projects for private and public organizations, where he has applied decision models in many contexts, such as risk analysis, reliability and maintenance, project portfolio, R&D project portfolio, project management, strategic modeling, outsourcing, information systems, supply chain, and water management. He has authored or coauthored more than 120 scientific papers in reviewed journals related to a variety of topics such as Operational Research, Group Decision and Negotiation (GDN), Decision Systems, MCDM/A (Multi-Criteria Decision Making and Aid), Risk, Reliability, Maintenance, Safety, Quality, and Water Resources and serves on the editorial board of some scholarly journals, including *GDN Journal*, *IMA Journal of Management Mathematics*, *International Journal of Decision Support System Technology*, and *EURO Journal on*

Decision Processes. He has been an active member of the main societies related to Operational Research, Group Decision, MCDM/A topics. Currently, he serves the GDN Section of INFORMS as Vice-President and served, until 2019, the council of the MCDM Section of INFORMS and the Executive Committee of the International Society on Multiple Criteria Decision Making. He is an Associate Research Fellow of the Institute of Mathematics and its Applications (FIMA). He also received in 2017 the INFORMS GDN Section Award.

João Luís de Miranda is adjunct professor (tenured) at College of Technology and Management (Portalegre Polytechnics Institute, Portugal) and researcher in Optimization methods and Process Systems Engineering (PSE) at CERENA (Instituto Superior Técnico, Lisboa). He has been teaching for about two decades in the Mathematics group (mainly Calculus, Operations Research, Numerical Analysis, Quantitative Methods, Multivariate Analysis), and he is author and editor of several publications in Optimization, PSE, and Education subjects in Engineering and OR/MS contexts. He is also interested in strength the referred subjects through international cooperation in multidisciplinary frameworks.

Emel Aktas holds a Chair of Supply Chain Analytics and Professor at Cranfield School of Management. She specializes in mathematical modeling, simulation, decision support systems, and statistical analysis to address supply chains problems, specifically in transport, retail, and manufacturing sectors. Her recent research focuses on food supply chain management, with one project (SAFE-Q) on minimizing the waste in food supply chains and another (U-TURN) on logistics collaboration practices for distribution of food in the cities. Her work has appeared in *European Journal of Operational Research*, *Interfaces*, *International Journal of Production Economics*, and *Computers and Human Behaviour*.

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CHAPTER 1

Implications of World Mega Trends for MCDM Research

Hannele Wallenius and Jyrki Wallenius

CONTENTS

1.1 INTRODUCTION

Digital technology is making rapid advances. The implications for people, companies, and societies are pervasive. It is difficult to foresee all the changes these developments will cause. Understandably, most individuals, many businesses and government leaders are not aware of, let alone prepared for the future changes. According to Brechbuhl from Dartmouth College, this ignorance was the driver behind the recent report, *Deep Shift: Technology Tipping Points and Societal Impact*, of the World Economic Forum.

The envisioned changes will bring about (1) digital connectivity, independent of time and place, and (2) tools for quickly analyzing vast amounts of digital data. In the World Economic Forum's report, the changes are grouped into six "mega-trends." We borrow freely from the report.

1. The Internet—world's access to the Internet will continue improving; people's interaction with it will become more ubiquitous
2. Further enhancements in computing power, communications technologies, and data storage, and the ability to interface with digital technology, anytime using multiple devices
3. The "Internet of Things"
4. Big data and Artificial Intelligence (AI)—the ability to access and analyze huge amounts of data; coupled with the "ability" of computers to make decisions based on this data
5. The sharing (or platform) economy and distributed trust (based on, for example, the block chain technology)
6. 3D-printing

These trends will greatly impact our lives, businesses, and governments—even universities—all around the world. As the World Economic Forum's Report astutely observes, our lives are increasingly being driven and enabled by software. The envisioned changes will be so profound and rapid that large segments of societies have difficulty in keeping up with the developments as users of technology.

The potential of the digital technology is huge, both in enhancing traditional industrial processes (robotics), and even more importantly in generating novel digital services. Many aspects of health care are also benefiting tremendously from new technologies. The digital revolution has begun, although decades (centuries) are needed for its full potential to be realized. One interesting cause of the Internet and social media (which totalitarian governments try to control) is the increased transparency of societies, which helps to improve democracy.

Besides technology mega-trends, there are other highly important mega-trends. These mega-trends, unlike technology mega-trends, are generally perceived as challenges or threats to humankind. Some

of them are discussed in PwCForesight#megatrends and by the World Economic Forum:

1. Demographic and social change taking place in many countries (aging populations, decreasing fertility, urbanization, refugee problem)
2. Increasing world population: growing need for food, clean water, and cheap energy
3. Climate change, concern for environment

The mega-trends, whether technology related or non-technology related, pose real concerns, challenges, or even threats to humankind. Most certainly, all of these mega-trends force governments and businesses to operate more efficiently under resource scarcity. Regarding technology mega-trends, privacy issues and security issues are not easy to solve, and today's societies are grappling with them. Moreover, with robots/AI "outsmarting" many individuals (with time, perhaps most individuals), what do most people do in year 2118? Brechbuhl asks the good question, "What will happen to the sense of worth, place, and contribution to society that human beings have derived from work throughout much of recorded history?" To make matters worse, who guarantees that the AI-driven robots are (programmed to be) friendly toward humankind?[1]

We choose technology mega-trends 1, 4, and 5, and non-technology mega-trend 3 from the World Economic Forum's list, for a closer look. What role can multi-criteria decision making (MCDM) play in them? How can MCDM help? What MCDM concepts will be useful? Recall that our lives are increasingly being driven and enabled by software. We think that it is a good starting point that many MCDM scholars can write their own software. Hence, we should be able to provide tools, software, and ideas to capitalize on rising opportunities and tackle problems resulting from the world's mega-trends.

1.2 INTERNET SEARCHES

E-commerce is continuing to transform commerce. To an increasing extent people make purchases online. Surprisingly (to us), besides travel and leisure industries, the clothing or fashion industry is almost driving the change. Typically when people buy online, they use some search engines, such as Google. It is not uncommon that the cheapest products

[1] Physicist Stephen Hawking (1943–2018), among other famous people, is concerned about this.

or services emerge on top of the list. A typical example is flight tickets between two cities. Incidentally, this apparently is forcing airlines to adopt the strategy originally followed by low-cost airlines of charging extra for better seats, meals, baggage, etc. One problem is that the search engines are not good enough in differentiating among offers (what they actually contain and how much customers value if a bag or meal is included in the price). MCDM scholars could develop better search engines! Search engines, which would not only be based on price, but other attributes as well. Keyword searches have their limitations.

Because of the abundance of offerings online, whether movies, music, or restaurant ads, many companies (and academics) have found it worthwhile to develop so called recommender systems. A recommender system is a subclass of information filtering systems that seeks to predict the "rating" or "preference" that a user would give to an item (Wikipedia). Recommender systems have become increasingly popular in recent years and are extensively used, for example, in choosing what movies to watch, what music to listen to, what news to watch, which books to read, and which restaurants to visit.

The underlying logic in recommender systems can be categorized into collaborative-filtering approaches and content-based–filtering approaches (Waila et al., 2016). Collaborative-filtering approaches are based on the idea of building a model from a user's past behavior as well as other users' behavior (items previously purchased). The logic of incorporating other person's likes is that if other people found this item (or similar items) popular, so would you! Content-based–filtering approaches develop a set of characteristics that an item possesses (which you liked) to recommend additional items with similar properties.

Consumers generally appreciate recommender systems. However, we hesitate recommending them to filter news items that one sees. If an individual is solely or largely dependent on reading news in social media, as opposed to traditional media, recommended (filtered) by a system, the set of news offered becomes narrow, representing a very narrow worldview. We think that in such cases, the recommender systems should periodically suggest different types of news, to broaden the person's horizon! (Of course, we are assuming that a broader horizon would be better than a narrower one.) But what such news would be, and how to do it, may not be trivial. It seems that Facebook CEO Mark Zuckerberg's ideas are different regarding the development of Facebook. In a recent interview by CNBC Business News and Finance, he says that Facebook will change its algorithm so that users will see less public content from businesses or publishers and more posts from their friends.

The logic underlying recommender systems should be understandable to MCDM scholars, although such systems have traditionally been developed and studied by computer scientists and AI scholars. We urge MCDM scholars to develop better recommender systems. Both MCDM and recommender systems are about modeling user's preferences (Lakiotaki et al., 2011).

Voting advice Applications (VAAs) are online systems to help voters find worthy candidates to vote for in national, presidential, and regional elections. Such VAAs are highly popular in many European countries, where sometimes more than half of the electorate use them. They are based on both the candidates and the voters answering a set of questions concerning political preferences. The system (the algorithm) then finds the candidates and party, which are "closest" to the voter's political preferences. The development of such VAAs involves solving many MCDM/behavioral decision-making problems. The questions must be discriminating, and there cannot be too many of them. They must have proper Likert-scales to make distance measurement meaningful. What distance measure should one use? Are the questions of equal importance to voters or should importance weights be used? If yes, how are they determined? Are voters interested in voting for candidates who have a higher likelihood of becoming elected?

Jyrki Wallenius (2017) gave a keynote on this topic at the Ottawa MCDM Conference. They also have a paper detailing the development of their VAAs and its implementation in Finland (Pajala et al., 2018). We urge other scholars to further work on their respective country's popular VAAs. It is an important problem, and in particular, in multi-party, multi-candidate elections, voters benefit from the use of such support provided by VAAs by making them much more aware of what the candidates stand for.

1.3 BIG DATA (AND ARTIFICIAL INTELLIGENCE)

According to a recent issue by *The Economist*, companies' most valuable resource is data. Data is being continuously generated from various sources, including cash registers, mobile phones, and Internet sites visited by millions of people daily. There is a realization by the corporate world that they should better use this data to their (strategic) advantage.

Typical advertising and marketing agencies or departments do not know how to analyze big data, even though they realize its importance or potential. The need for people possessing analytics skills is high.

What role does big data play in advertising? In a nutshell, big data can be used to help create targeted and personalized campaigns that increase the efficiency of advertising or marketing. How is this done? Simply by gathering information and learning about user behavior. Many reward and loyalty programs are based on the use of consumer data. Recommender systems use past purchases or searches to make new recommendations. An interesting phenomenon is the use of social media by ad agencies. It is easy to document and share experiences as customer or consumer in social media. It is not uncommon that thousands of people read these posted reviews and are influenced by them. The world of social media offers interesting research opportunities to help businesses but also to understand human social behavior (Ghosh et al., 2017).

Another area where big data will find its uses is medicine or health care. Various monitoring instruments continuously generate data, as do human genome studies. They eventually lead to better preventive and actual care and more accurate diagnostics. An interesting problem from the perspective of MCDM is how to better incorporate patients' views on their own healthcare plans and treatment decisions. A more general level concern in health care is to make the system more efficient and more personalized. Healthcare decisions naturally have to deal with multiple criteria, and complex tradeoffs between cost, the quality of care, and even potential loss of lives. Wojtek Michalowski's (University of Ottawa) work is a good example of the type of impactful work a person with an Operations Research/MCDM background can do in health care. Jack Kitts (2017), President and CEO of Ottawa Hospital, gave a keynote at the Ottawa MCDM Conference, in part, based on Michalowski's collaboration with the hospital.

AI is a tremendously important field today. Part of the work uses Kohonen's neural nets (Kohonen, 1988). The idea is to build learning "robots," which could eventually make decisions on behalf of humans. An example is self-driving automobiles. Such "robots" need to be programmed to follow certain rules. They must make complex moral choices as well. Work is also currently being conducted to incorporate emotions into "robots." We ask, whose emotions? Our personal view is that we would hesitate to delegate decision-making powers in important matters to "robots," no matter how "intelligent" they are. We feel that humans should be in control of their own lives. AI is a good tool, but a dangerous master—something the ancient people said of fire.

1.4 THE SHARING (OR PLATFORM) ECONOMY

According to Wikipedia, *sharing economy* is an umbrella term with a range of meanings and is often used to describe economic activity involving online transactions. It grew out of the open-source community and referred to peer-to-peer–based sharing of resources and access to goods and services. The term is often used in a broader sense to describe sales transactions conducted via online market places (platforms). Online auctions are an example of such a market place, which have been around since late 1990s. Newer examples include the San Francisco-based taxi company, Uber, and an online market for housing, Airbnb. The clever innovation of Uber is that all that is needed is a platform where owners of cars and people in need of rides or deliveries can communicate. Uber is now operating globally in some 600 cities, without owning any vehicles. Airbnb is an American company which hosts an online marketplace and hospitality service for people to lease or rent short-term lodging, including vacation rentals, apartment rentals, homestays, or hotel rooms (Wikipedia). They currently have some three million listings. In the case of Airbnb what is needed is a platform where supply and demand for short-term housing meet. Another example of a sharing economy is crowdfunding and other peer-to-peer–lending sites, where private people (instead of banks) can lend money to people in need of money. Obviously, the interest rates are relatively high.

Our personal involvement with the sharing economy goes back to late 1990s, when we worked on developing a multi-attribute auction site, called *NegotiAuction* (Teich et al., 2001). We realized that price-only auctions were too simplistic and that auctions (transactions in general) need to include other aspects as well, such as quality and terms of delivery. Our *NegotiAuction* system was based on "pricing out" all other attributes besides cost. Today there exist many such commercial multi-attribute auction sites (Pham et al., 2015). More recently, we have investigated the success factors underlying crowdfunding campaigns (Lukkarinen et al., 2017). Generally speaking, many MCDM scholars are equipped with the skills to develop online platforms. We urge them to do so! There is a growing market for them. In sharing-economy platforms, some type of matching based on preferences is sought, where supply meets demand. The matching problem is a classic problem in economics (Pissarides, 2000). Lessons could be learned from economics as well as from MCDM.

1.5 CLIMATE CHANGE, CONCERN FOR ENVIRONMENT

Human-induced climate change is highly probable. B. Feltmate's (2017) keynote address at the Ottawa MCDM Conference dealt with it. The concern for the environment is almost universal. Most countries have signed the Paris Accord. Sustainable development is the keyword. When making decisions, corporations are increasingly forced to consider the impact of their decisions on the environment. If they fail to do so, consumers may boycott their products.

Generally speaking, environmental applications are probably the most common applications among MCDM studies. It naturally requires decision makers to consider multiple criteria and complex tradeoffs between them. See, for example, the book by Hobbs and Meier (2003). Another case in point is flood-risk management, an area, which is growing in importance because of climate change (deBrito and Evers, 2016). We believe that many models being used by various environmental authorities in the world may not be up to date in terms of the MCDM community's standards. We should increasingly get involved in helping model and solve problems related to the environment. It is our core business!

1.6 HOW IS MCDM CHANGING?

We have already seen the trend from multiple-objective optimization toward decision support. We are no longer so fixated on trying to find "optimal" solutions to problems, but supporting decision makers in many reasonable ways. The role of transitivity is probably eroding, as predicted by Fishburn (1991), although orthodox decision analysts do not see it that way. Heuristics are becoming more and more important. One good example is Evolutionary Multi-Objective Optimization (EMO), which consists of heuristic tools mimicking the survival-of-the-fittest ideas in nature (Deb, 2001). Although it is a relatively new field, it is doing great. Originally developed mainly for bi-objective problems, with the purpose of generating all approximately Pareto-optimal solutions, much recent research has focused on developing hybrid interactive-EMO approaches for multiple-objective problems.

The importance of the psychology of decision making, or behavioral decision theory, is being rediscovered. Three Nobel Prizes in Economics have been awarded to decision psychologists: the first to Herbert Simon[2]

[2] Obviously Herbert Simon is much more than one of the father's of behavioral decision theory. He is also regarded as the father of AI.

in 1978, the second to Daniel Kahneman in 2002, and the most recent to Richard Thaler (2017), whose work builds on Daniel Kahneman and Amos Tversky. We take a pragmatic view to the importance of behavioral issues in decision making. We think that the more realistic our tools are from a behavioral perspective, the better our chances to support individual decision makers. Hence, there is a need for improving the incorporation of decision psychologists' findings into our decision-support tools. Kahneman and Tversky's research takes us a long way. We also think that there is an increased awareness of the fact that situations vary and the needs of decision makers vary. In some cases there is a need for more formal analysis than in other cases. Sometimes, quick-and-dirty intuition may be all that is needed.

The Internet is changing the concept of who a "decision maker" is and what type of support he or she needs. We have largely been in the business of supporting corporate leaders and managers. How many corporate leaders are there in the world? A few million? But there are 4–5 billion consumers who shop online. Many of them could use some support when making purchasing decisions on the Internet. Such decision support must be targeted at masses; hence it must be simple. We think, in addition to complicated algorithms and decision-support tools, there is a need for developing simple tools to be used by the masses.

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