Focusing on Important Problems [1]

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Research in Multiple Criteria Decision Making (MCDM) and its subfields (multi-attribute utility theory or Decision Analysis, AHP, Goal Programming, MCDA, multi-objective mathematical programming, EMO) is very active. However, our general feeling is that bright, young people do not focus their energies sufficiently on solving important problems despite many very important problems that deserve attention. Some of the problems are critical to the well-being of the world. The purpose of our essay is to identify these very important problems (or mega trends, as they are sometimes called) and briefly discuss how the research community could help solve or at least alleviate such problems. The reader could interpret our essay as suggestions for a research agenda or program. It does not matter whether we are AHP scholars, multi-objective optimizers, or decision analysts, everyone's contribution is needed.

In 2015, the World Economic Forum published a report titled *Deep Shift: Technology Tipping Points and Societal Impact* which discussed ongoing technology mega trends. The report, which classifies the technological mega trends into the following six categories, is still relevant today.

1. The Internet – The world's access to the Internet will continue improving; people's interaction with it will become more ubiquitous (at least in the western world).
2. Enhancements – Further enhancements in computing power, communications technologies, and data storage will take place.
3. The "Internet of Things" – This will be developed to a fuller extent.
4. Big data and Artificial Intelligence – The ability to access and analyze huge amounts of data; coupled with the 'ability' of computers to make decisions based on this data.
5. Sharing and platform economies – These will play an even larger role in the future than today.
6. 3D-printing – This will play a more important role in industrial processes than today.

[1]Our article is a much shorter and updated version of a paper which was recently published in *Intelligent Decision Support Systems*, (Eds.) S. Greco, V. Mousseau, J. Stefanowski, and C. Zopounidis, Springer, 2022.

In addition to technological mega trends, the world is facing other very important "challenges" or even threats to humankind (non-technological). Some of them are discussed by the World Economic Forum.

1. Demographic and social change taking place in many countries and many continents (aging populations; decreasing fertility; urbanization; refugee problem)
2. The world population (in particular, in India and Africa) continues to increase, causing a growing need for food, clean water, and cheap energy
3. Climate change, concern for the environment
4. Conflict resolution and disarmament
5. Possible future pandemics and economic impacts of wars

In our essay, we will discuss technology mega trends 1, 4, and 5 and non-technology mega trends 3, 4, and 5 from the above World Economic Forum's lists in more detail. What role can decision analysis/multi-objective optimization, AHP, and preference modeling play to help alleviate the problems?

What can we as an MCDM profession do?

We argue that the MCDM profession is in an excellent position to help solve problems caused by world mega trends by developing tools and software and generating novel ideas. The world is increasingly driven by software and algorithms, and algorithm development is something we have been involved in for over half a century. The analytics skill set required in this type of work is very natural to MCDM professionals as is human-computer interface development. Moreover, the very central concept (in our field) of nondominance (or efficiency or Pareto-optimality) is at the core of many challenging decision problems. When resources are limited, it is imperative to understand tradeoffs. Matching (of supply and demand and interests) is based on how well preferences or needs of both parties are modeled. It is also important to understand risks and conflict resolution. All of these skills are increasingly needed now and in the future – and MCDM professionals can help.

Internet searches and recommendations

Perhaps because of the pandemic, online shopping or multi-channel shopping is growing faster than originally expected. This growth has many implications. The activity of online shopping has generated many interesting research questions for strategy, marketing, and supply chain scholars to name a few. An observation concerning our field is that many consumers who buy online could benefit from some support when making purchasing decisions on the Internet. Such decision support must be targeted at the masses and must be simple.

When people buy online, they often use search engines to help them find products or services. Search engines allow users to specify what they want. Typically, this is done via (hard) constraints related to the specific search; for example, an upper limit for the price of the product or service, location of the rental house, or the type of car (ride). Search engines commonly ignore features other than these constraints and rank order the products/services based solely on price. MCDM offers tools that allow multiple factors (or attributes) to be incorporated. Which tools are best suited for the purpose of internet searches is a subject that needs to be researched. For an attempt at improving search engines, see Roy et al. (2008).

To combat the information overload phenomenon, many companies (and academics) have developed, so called, recommender systems[2]. Wallenius & Wallenius (2022) reported the following:

> Recommender systems are extensively used, for example, in choosing movies to watch, music to listen to, news to follow, books to read, and restaurants to visit. Recommender systems are based on the "similarity" logic…The human desire for variety is not important in this logic. The assumption is that people lack curiosity and the desire to experiment. We think that the recommender systems should periodically suggest different types of products/services (or news), to broaden the person's horizon. How to operationalize this idea, calls for research. (p. 63)

Big data (and Artificial Intelligence)

Data is continuously being generated from various sources including individuals (consumers) who constantly generate data by visiting the Internet. Many corporations are realizing that they should better utilize data to their (strategic) advantage. Big Data and AI are proving highly valuable in the following problem domains:

1. Strategy development and management practices: Schildt (2020) provides an in-depth look at how data and algorithms are reshaping management practices, organizational structures, corporate culture, and work roles.

2. Advertising: The role of big data in advertising is growing in importance, allowing companies to target individuals and customer segments.

3. Medicine and health care: Big data will increasingly find uses in medicine and health care. Healthcare decisions naturally involve multiple criteria, and complex tradeoffs between cost, the quality of care, even potential loss of life.

Artificial Intelligence (AI) is currently an important field and will continue to develop in importance. However, AI is not only about hi-technology, but involves many complex legal and ethical issues that must be solved. Interestingly, in 2019 one of the Wallenberg Foundations in Sweden launched a program to fund research focusing on analyzing potential ethical, cultural, economic, labor market, socio-economic and legal aspects of the technology transition, including AI. We personally hesitate to delegate decision-making powers in important matters to 'robots' no matter how 'intelligent' they are. Humans should be in control of important decisions that will impact their lives.

Platform and sharing economies

Concern for the environment is driving sharing and circular economies. A sharing economy needs online platforms where supply meets demand and where some type of matching based on preferences is sought. An example of an online marketplace is an online auction, which has been around since the late 1990's. Newer examples are the

[2]We share the criticism voiced in the following quote from e-Commerce Relevance Report 2022 (by COVEO). "Sky high expectations crushed by frustrating search and irrelevant recommendations."

San Francisco-based taxi companies, Uber and Lyft, and the online market for housing, Airbnb. Does matching work optimally in markets like these?

In the late 1990's, we worked with the platform economy concept and developed a multi-attribute reverse (or procurement) auction site, called *NegotiAuction* (Teich et al., 2001). We realized that price-only auctions were too simplistic and that auctions needed to include other aspects as well, such as quality and terms of delivery. Our *NegotiAuction* system was based on 'pricing out' (or costing out) all other attributes besides cost (see Keeney and Raiffa, 1976). Many commercial multi-attribute auction sites exist today (Pham et al., 2015).

Climate change, concern for environment

The concern for the environment is almost universal. Environmental studies naturally require the decision-makers to consider multiple criteria and the complex tradeoffs between them (Hobbs & Meier, 2003). These types of decisions offer many application opportunities for MCDM professionals.

From the MCDM's perspective, an under-researched topic is sustainable (or green or ethical) investing. Markowitz (1952)'s original portfolio optimization model had two objectives, maximizing expected returns and minimizing risk (or volatility). Now, many investors (including institutional investors) also want to consider how companies perform in terms of a third dimension of sustainability (or Environmental, Social and Corporate Governance, for short ESG, criteria). However, measuring sustainability is far from a trivial task. Sustainability is multi-dimensional, and measuring it requires research in which our community should help. Interesting early work has been reported in Hallerbach et al. (2004).

Conflict resolution and disarmament

This year, conflict resolution and disarmament has become as important as it was in the 1960's due to the war in Ukraine (see Saaty, 1968; Saaty et al., 2022). Saaty's ideas from 1968 are as relevant today as ever. In fact, Saaty's work at the State Department and in the Geneva negotiations with the Soviets concerning nuclear arms reduction served as a catalyst for his development of the AHP method (Saaty, 1980). Saaty et al. (2022) is based on the contributions of the AHP in conflict resolution, in particular the Israeli-Palestine conflict. More research and real-world implementations are needed.

Possible future pandemics and impacts of wars

The recent COVID-19 pandemic and the war in Ukraine have taught the world the importance of risk analysis and the necessity of being prepared for future crises. Safety-stocks of important (critical) materials need to be large enough for a country (the world) to survive, but this involves a tradeoff with cost. The MCDM field offers tools to gauge risks and decide the appropriate levels of critical materials storage.

Due to disruptions in foreign supply chains (a case in point is the energy shortages prevalent in Europe), each country needs to carefully consider the possibility of improving its self-sufficiency in critical areas. This calls for difficult tradeoff and risk analyses. Big data offers tools to combat disinformation campaigns, especially prevalent in times of war.

Conclusion

The future of MCDM looks bright. Many of the world's mega trends reinforce the role of MCDM by pointing out novel application areas. The MCDM community needs to seize these opportunities. The world is getting more complex and despite the relative affluence of the world, resource constraints still prevail. Because of resource constraints, we cannot achieve everything we want, and tradeoffs must be made. The concepts of efficiency (or Pareto optimality) and tradeoff are at the core of MCDM.

This is a summary of our suggestions in areas where we see great potential for novel contributions of MCDM:

1. Develop better recommender systems and search engines.
2. Develop better matching algorithms for various situations.
3. Promote the use of big data in companies and the public sector.
4. Develop better measures (indices) for sustainable investing.
5. Develop decision support tools targeted at the masses to help consumers make online purchasing more efficient.
6. Produce theoretical and applied work on conflict resolution.
7. Work on risk analysis, and improving the preparedness of organizations, countries, and regions for eventual crises.

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