MULTI-CRITERIA DECISION MAKING: DO ECONOMIC AND ENVIRONMENTAL OBJECTIVES CONFLICT?

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Every person, business, organization and government faces a complex problem of planning for the sustainable future. On one side, we are experiencing highly unpredictable environmental changes due to human-related activity and those changes should be minimized. On the other side, we live in the world of limited resources and the need for economic development. Those two needs seem to conflict with one another. For example, if we would like to have clean air to breathe, but also want to use cars for transportation, our needs might conflict. Which would we choose and how would we make our decision? The goal of sustainable development assumes that meeting the needs of the future depends on how well we balance economic and environmental objectives – or needs – when making decisions today.

It is widely accepted that we are facing with a massive decision-making optimization problem in order to ensure sustainable development. The single old-fashion objective of every business that is maximizing profit (or minimizing costs) is becoming obsolete. Now, we have at least two conflicting objectives in our decision making and those are minimizing environmental impact and maximizing expected profits. Moreover, the problem of minimizing environmental impact is complex by itself as it consists of minimizing use of fossil fuel, maximizing carbon sequestration, optimizing our use of energy, etc. Due to these facts mathematical modeling and operations research techniques are required to tackle these decision-making multi-objective optimization problems.

Mathematical modeling and optimization techniques are utilized in many areas of engineering and science to improve performance. The main challenge of practical models is minimizing different risks in the presence of uncertainty and it requires optimizing over a number of conflicting objectives. In this study, we show examples of practical management problems that demonstrate how mathematical modeling combined with optimization algorithms that we developed is used to find better solutions and improve decision-making.

The common feature of management and technological models is presence of multiple performance indicators (profit, cost, return on investment, environmental impact) and risk measures (risk of flooding, risk of water supply deficit, volatility of project costs, etc.). Due to that all these models are multi-objective problems. The solution of a multi-objective optimization problem is a set of Pareto efficient points, known as Pareto efficient trade-off frontier. We present our methodology that allows computing Pareto efficient frontiers efficiently.

One of the risk management problems that we use to illustrate our computational algorithms is management of the water resources of a lake. Exploitation of water resources inevitably produces conflict among different objectives. In order to arrive at an acceptable compromise, the decision-makers should seek an optimal trade-off between conflicting objectives that reflect the priorities of various decision-makers. Those objectives include minimizing flood damage, minimizing water supply deficit, minimizing project cost, minimizing environmental risk and minimizing financial risk of the project among others. In this study, we demonstrate our algorithmic approach to computing Pareto efficient trade-offs for this multi-objective optimization problem, where economic benefits should be balanced with associated negative environmental impacts. We show a practical example demonstrating computation of the 3D efficient trade-off frontier when multiple objectives include minimizing flood damage, minimizing water supply deficit and minimizing project cost.

Another our case study involving multi-criteria decision-making describes modeling improved store design to help meeting greener goals at newly planned locations. A fast-food restaurant chain wants to reduce the environmental impact of their business while maintaining the company's high level of customer service. Resulting designs are ranked based on customer service level and environmental impact (defined as the average quantity of emissions produced by customer vehicles using parking lot and drive-through lane). The simulation model that we developed computes multi-objective optimal solution trade-off to meet these goals.

There are some cases when economic objectives do not conflict with environmental needs. One such problem is minimizing border crossing delays for commercial trucks. Border delays lead to increases in shipping cost and increase in the environmental impact caused by emissions from the vehicles at the border. Using historical data on truck arrivals, processing times, staffing patterns, etc., we developed a simulation model of the border, identified the problems and their sources, and proposed a solution to the border congestion problem providing the largest improvement (including environmental benefits) for the least cost. Another management problem where environmental and economic objectives coincide is optimizing supply chain. Minimizing delivery time objective leads to minimizing environmental impact (due to minimizing greenhouse gas emissions caused by transporting goods).

Our computational results demonstrate relative performance of multi-objective optimization formulations for a number of practical problems. We briefly discuss performance of our optimization formulations with respect to different factors. Presented models and problem formulations were developed by McMaster University and other academic researchers in co-operation with business partners and are aimed for practical implementation and use by risk and environmental managers at different institutions and industrial enterprises. A number of software tools combined with optimization solvers are used for modeling and computations.

In conclusion, innovation, technological advances and modern information technology including operations research and optimization will be the leading forces driving sustainable development and rational use of natural resources.