Mathematical optimization for decision-making under decision-dependent uncertainty

Companies and policymakers take decisions under high levels of uncertainty. To deal with this uncertainty, they usually design a-priori plans that can easily be adapted when uncertainty is revealed. Most approaches in the scientific literature that deal with uncertainty in decision-making assume that the uncertain parameters (e.g. cost, demand, etc) can be observed *for free* and that the sequence in which they are revealed is independent of the decision maker's actions. Yet these assumptions fail to hold in many real-world applications where the *time of information discovery* is decision-dependent and the uncertain parameters only become observable after an often-costly investment. To fill this gap, optimization models need to be developed in which part of the decision variables control the time and amount of information discovery.

This PhD project aims at making major advancements in this area of research by developing innovative models and algorithms using state-of the-art operations research tools such as linear and non-linear programming, benders decomposition, column generation, branch-and-price, cutting planes, etc. The project aims at solving both two-stage and multi-stage problems with objective and/or constraint uncertainty. The developed models and algorithms can be applied in several settings such as:

Transportation: discover information on customer demand (e.g. using sensors to monitor the level of waste in a container) to design efficient and sustainable distribution/collection routes

Inventory management: Improve inventory record accuracy (e.g. using RFID technology) to design efficient inventory control policies

Healthcare: decide on the set of tests to run to make an accurate and timely disease diagnosis

Questions related to this PhD project should be sent to Said Dabia (s.dabia@vu.nl).

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Operations management for a sustainable economy

Concerned citizens and politics have initiated the move to a sustainable society. Both exert pressure on businesses to comply with this requirement, creating tremendous challenges and opportunities. Although the ambition of sustainable development (“meeting the needs of the present without compromising the ability of future generations to meet their own needs”) sounds great, implementing it presents large obstacles. Operations research and operations management (OR/OM), however, offer a wide spectrum of tools to improve business processes and pave the way to reconciling economics and ecology.

Below, we sketch five concrete directions for a PhD project to contribute to the reshaping of society, fitting a pattern of sustainable production and consumption. These research directions will be developed further in collaboration with the preferred candidate.

Generic systems thinking model to assess supply chains on sustainability

This project is mainly about including dynamics in the transition to a sustainable economy

Sustainability and digitalization

New developments in IT (e.g., blockchain) offer new options for a circular economy

The role of the consumer

The consumer in the end decides, so emphasizing his or her behavior in analyses is crucial

The environmental impact of online grocery retailing

Online and offline grocery retailing differ in many respects, also in terms of sustainability

Life cycle optimization

OR/OM offers a lot of potential to analyze and improve over the entire life cycle of products and services

Questions related to this PhD project should be sent to Reinout Heijungs (r.heijungs@vu.nl).

Emerging trends in urban logistics:
The impact of stakeholder behavior on decision making and sustainability

Societal trends such as urbanization, desire for flexibility, and growing awareness about climate change and sustainability impose severe challenges for distribution logistics providers and require re-thinking and re-designing current distribution strategies. These challenges**,** however, have also led to a variety of new opportunities that are currently studied both in theory and practice. Current trends include, e.g., crowd-shipping, the use of autonomous vehicles or offering alternative delivery locations such as parcel lockers. A main shortcoming of the analysis of these trends is that recent (scientific) studies typically neglect or oversimplify the impact of non-corporate stakeholders (such as crowd-shippers and end-users) and their behavior. These stakeholders may act selfishly and behave either strategically, or their objectives and utilities may be in conflict with the operators' goals of efficiency and sustainability.

This project aims to incorporate more realistic stakeholder behavior and (partially unknown) stakeholder preferences to model and solve more realistic (distribution) logistics problems. Moreover, the goal is to analyze the impact of stakeholder behavior on sustainability and ideally to develop ways to stimulate the sustainable behavior of stakeholders. To this end, potential candidates shall design and implement models and algorithms based on mixed-integer (linear and non-linear) programming or bi-level optimization, and evaluate them via extensive computational studies.

Questions related to this PhD project should be sent to Markus Leitner (m.leitner@vu.nl).

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Learning to optimize:
The application of learning tools to improve optimization algorithms

In the last few years, researchers have become increasingly interested in learning algorithms to improve existing optimization methods [1].
As an explanatory example, take the vehicle routing problem (VRP) that a logistics company might need to solve daily. Many features are specific for that company and historical data can be used to improve the performance of the VRP algorithm in the setting of the company. Such learning from data can be applied in many ways. In heuristics, one could train a learning algorithm to estimate the value of partial solutions based on instance features such as capacities, average distance, etc. This obtained information can be used to speed up the algorithm and improve the solution found. Alternatively, a heuristic could learn from its own decisions and adjust its behavior accordingly. Apart from heuristics, learning is more and more used within advanced combinatorial techniques [2] such as column generation or branch and bound and within areas such as robust optimization (where we learn about the sensitivity of a solution to changes in the data) and in algorithmic game theory (where we can achieve near-optimal mechanisms without the need of specific assumptions on the population).
This PhD project aims to contribute to the research area of applying learning to improve optimization algorithms by focussing on a particular direction which will be specified further based on the candidate's skills and interests and in conjunction with researchers from the Operations Analytics Department.

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Questions related to this PhD project should be sent to René Sitters (r.a.sitters@vu.nl).