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Managing Safety of Heterogeneous Systems

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Abstracts

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Contents

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Uncertainties in Disaster Risk Management: an Overview

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Keywords: disaster risk, quantitative risk assessment, uncertainties, aleatoric uncertainty, epistemic uncertainty, operational uncertainty, situational uncertainty

1. On the nature of the uncertainties in risk assessment

In a very comprehensive study, Compton et al (2003) described how the concept of risk and definition of uncertainty vary according to technical field.

- A statistical or actuarial approach is typically used in the insurance community. In this, both probabilities and consequences are considered explicitly. However, they are included together by the use of "expected value of the damage" as a measure of risk.
- The health and environmental protection community typically focuses on the magnitude of adverse consequences as a measure of risk, most frequently by attempting to keep adverse consequences of certain agents below a certain level determined to be "acceptable" or "safe".
- In safety engineering a scenario to be avoided is identified (e.g., destructive flooding, release of radioactivity from a nuclear reactor, etc.) and the "risk" is the probability of occurrence of the adverse event. In traditional flood protection, for example, a typical goal is to reduce the probability of flooding to below a certain design value, such as a hundred year flood (i.e., the probability of flooding in any year should be less than 1%).
- Integrated approaches determine a "Risk curve" or CCDF (complementary cumulative distribution function) to characterize the risk, which plots the magnitude of an event on the horizontal axis vs. the probability or the frequency of exceeding that magnitude on the vertical axis. The use of a log-linear scale allows a much finer resolution of the characteristics of low probability events. The risk curve might be quite useful because it represents both the probability and the consequence in an explicit manner.

Aleatoric and epistemic uncertainties have been so far explicitly considered in risk assessment procedures (see Helton and Burmaster 1996). Aleatory uncertainty arises from the natural variability of the system under study when they are fundamentally stochastic in nature and their future state cannot be predicted deterministically. Epistemic uncertainty refers to a lack of knowledge about the system and can be introduced by errors or by limitations on the ability to collect samples. By taking into account such kind of uncertainties the integrated approaches result in families of risk curves by convolution or Monte Carlo procedures, as determined in an example referred to risk of flash floods in Vienna (Compton et al. 2003). This finding demonstrates that

- on the one hand, uncertainties need to be considered when deriving risk figures, since point values (obtained by best estimate of each variable) may be meaningless;
- on the other hand, decisions can be much more difficult because the analysis does not result in a single optimum value for benefit-cost analysis.

Policy decisions are even more complicated by the existence of operational uncertainties (Amendola 2001) unavoidable and difficult to quantify. The term "operational" may include a number of different issues linked with the choices performed by an analyst (or a team of analysts), such as:

- The implicit or explicit assumptions about the "nature" of probability, and choices among databases, and within a same data base;
- The choice of the modelling for hazards identification and for structuring the quantification of the event frequencies.
- The choice and the way of using the physical models (which may add further uncertainty in addition to that implied by the model or epistemic uncertainty);
- The bias introduced by the context (e.g. a regulatory environment, which sometime prescribes certain parameters and/or models; time and resource constraints; boundaries assumed; etc.)
- The basic experience of the analysts and his operational background (i.e. unintended bias).

2. On the nature of the uncertainties in emergency management

A fundamental attention must be paid to the management of uncertainties in early warning systems and in the communication of major hazards, as well as to conflicts in decisions with respect to financial costs and social disruption. To be effective, the warning process should utilize the integrated effort of scientists, administrators, and the public. Only by such integration, and in presence of high social cohesion, can systems efficient in the case of real hazard occurrences and robust enough to resist disruption from false alarms be implemented. Despite the time that has elapsed since its proposal, the in-field work of De Marchi et al. (1993), after interviews with leading responsible persons in emergency planning and management, resulted in a classification that still now provides a very useful framework for understanding the nature of the uncertainties to be managed. In addition to scientific uncertainties (difficulties in risk assessment or forecasting), the other dominating uncertainties are

- situational: inadequate available information in relation to the necessary decisions
- legal/moral: possibility of future liability or guilt for actions or inaction
- societal: high when there is little integration between the public and concerned institutions
- institutional: the withholding of information by agencies for bureaucratic reasons
- proprietary: contested rights to know, warn or conceal (especially these concerning technological risks).

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Robust Expansion of Agricultural Production in Ukraine under Uncertainties

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Keywords: rural developments, the Ukraine, robust expansion of agricultural production, uncertainties, stochastic optimization model

In Ukraine, the growth of large-scale agricultural enterprises with specific focus on cash crops production causes imbalances of agricultural production, undermines food security, contributes to the deterioration of social, demographic and cultural conditions in rural areas. Ukraine has important natural and labor resources for future rural developments. For example, 70% of agricultural production is still managed by small and medium farmers despite the difficulties associated with market instabilities, lack of sufficient credits and governmental support. The main challenge is to use these resources in a sustainable way to enforce rural communities and sustainable agriculture. This requires integrated methodologically sound approaches to planning agricultural production expansion including better fiscal conditions and tax distribution.

In this talk we present a stochastic geographically explicit model for the analysis of robust agricultural production expansion and rural development strategies under different criteria for example, to satisfy the requirement ensuring safe local production levels consistent with the country-wide food security targets. We discuss application of the model with selected results on the level of Ukrainian oblasts'.

Operating on Second Order Distributions in Decision Analysis

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Keywords: decision analysis, imprecise probabilities, imprecise utilities

Using second order information during the evaluation of a decision tree, the operations involved are multiplications and additions. There are therefore two effects present at the same time when calculating combined distributions over expected utilities in decision trees. Those are additive effects (for joint probabilities aggregated together with the utilities at the leaf nodes) and multiplicative effects (for intermediate probabilities).

One important effect is that multiplied distributions become considerably warped compared to the corresponding component distributions. Such multiplications occur in obtaining the expected utility in decision trees and probabilistic networks, enabling discrimination while still allowing overlap. Properties of additions of components follow from ordinary convolution.

We will discuss some aspects of the combined effect and consider how to put second order information into use to further discriminate between alternatives. The main idea elaborated upon herein is not to require a total lack of overlap but rather allowing overlap by interval parts carrying little belief mass, i.e. representing a very small part of the decision-maker's belief. Then, the non-overlapping parts can be thought of as being the core of the decision-maker's appreciation of the decision situation.

Various Types of Objective Functions of Clustering for Uncertain Data

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Keywords: clustering, objective function, uncertainty, tolerance, optimization

Clustering is known as very useful tools in many fields for data mining. We can find the construction of the data set through the clustering methods.

Now, the more the ability of computers increase, the more works for uncertainty have been studied. In the past, data handled by the computers was approximately represented as one point or value because of poor ability of the computers. However, the ability is now enough to handle data with uncertainty called uncertain data. Therefore, a lot of researchers have tried to handle original data from the viewpoint that the data should been represented as not one point approximately but some range exactly in a data space. The goal of this paper is to show some clustering methods for uncertain data.

Whenever we construct the clustering methods for uncertain data, we have one problem, that is, how should we present the uncertainty of data ? The most typical way is to use the concept of interval, i.e., $[\underline{x}, \overline{x}] = [(\underline{x}_1, \dots, \underline{x}_p), (\overline{x}_1, \dots, \overline{x}_p)] \subset \Re^p$. However, the way has the following problems.

1. We often construct the clustering methods through the methodology of optimization. If we present the data as an interval, it becomes difficult to formulate the problem in the framework of the optimization.

2. The dissimilarity between data, which plays very important role to construct clustering algorithms, is defined by distance. There are many distances between intervals but we do not have the guide to select the suitable distance. Moreover, many distances between intervals do not satisfy the axiom of metric.

To solve the above problems, we have proposed "tolerance" of an convenient tool to handle data with uncertainty [1] and applied some of clustering algorithms [2, 3, 4, 5]. In our proposed tolerance, such data is represented by $x + \delta = (x_1 + \delta_1, \dots, x_p + \delta_p) \in \Re^p$ and a constraint for δ_j like that $|\delta_j| \leq \xi_j$. If we assume x_j to be $(\overline{x}_j + \underline{x}_j)/2$ and ξ_j to be $|\overline{x}_j - \underline{x}_j|/2$, the formulation is equivalent to interval.

We can handle data with uncertainty in the framework of optimization by the concept, without introducing some particular distance or measure between intervals. For example, let's consider calculation of distance $d(X, Y)$ between $X = [\underline{x}, \overline{x}]$ and $Y = [\underline{y}, \overline{y}]$. We have to introduce some measure between intervals to calculate it, e.g., $\min\{\|\underline{y} - \overline{x}\|, \|\overline{y} - \underline{x}\|\}$ (minimum distance), $\max\{\|\underline{y} - \overline{x}\|, \|\overline{y} - \underline{x}\|\}$ (maximum distance) or $\max\{\|\overline{y} - \overline{x}\|, \|\underline{y} - \underline{x}\|\}$ (Hausdorff distance). However, if we use tolerance, we don't need any particular distance, that is, a distance $d(X, Y)$ between $X = x + \delta_x$ ($\|\delta_x\| \leq \xi_x$) and $y = y + \delta_y$ ($\|\delta_y\| \leq \xi_y$) can be calculated as $\|(x - y) + (\delta_x - \delta_y)\|$. From the above, we know that this tool is useful when we handle the data, especially data with missing values of its attributes, in the framework of optimization like as fuzzy c-means clustering [4].

In this paper, we will show some clustering methods for uncertain data by the concept of tolerance. The procedures to construct these methods are based on fuzzy c-means, i.e,

- An objective function is defined.

- Some solutions which minimize the objective function are derived.

- An clustering algorithm is constructed using the solutions.

It means that the whole algorithm depends on the objective function. Therefore, we will introduce various types of objective functions for uncertain data to construct the clustering algorithms.

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Risk, Security, and Robust Solutions

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Keywords: risk, security, robustness

Standard risk analysis deals with threats generated by exogenous chances. Typically, such situations allow to separate risk assessment from risk management. Available data are used to characterize risk by a probability distribution that is then used for integrated risk management based on proper decision support models. As it was discussed at the previous IIASA/GAMM workshop, the statistical decision theory, the expected utility theory and more general stochastic optimization (STO) theory provide common approaches for this purpose.

Security analysis, in addition to the standard risk analysis, also requires dealing with threats generated (intentionally or unintentionally) by intelligent agents. An obvious example is terrorism. Less evident examples are floods which are often triggered by rains, hurricanes, and earthquakes in combination with inappropriate land use planning and maintenance of flood protection systems. Anthropogenic climate changes may increase frequencies of extreme weather-related events and in addition to floods lead to shortages of flood and water. In rather general terms, water and food security analysis has to deal with robust functioning of complex multi agent food and water supply networks whose disruption by the lack of strategic policies, malicious acts, weather related extreme events, shocks of market prices, or faults of regulations may cause malfunctioning of local communities with potential global spill overs. Risks associated with such problems are usually affected by decisions of different agents, i.e., their assessment should not be separated from risk management. Say, a decision of a planning "agent" (agency) regarding the biofuel production may seriously affect behavior of other agents, change market prices, induce threats of environmental degradation, destabilize supplies of food and water. In other words, involving endogenous risks should not be characterized by a single probability distribution. In general, they are implicitly defined by probabilities dependent on decisions of different agents. Additional methodological challenges in security analysis arise in situations involving potential malicious acts that may require assessment of randomized solutions.

Inherent uncertainties of complex interacting systems restrict exact evaluations and predictions. The main issue, in this case is the assessment of robust solutions: although exact evaluations are impossible, the preference structure among feasible decisions may provide a stable basis for relative ranking of alternatives in order to find solutions which are optimal, in a sense, against all potential uncertainties. As we know, the heavier parcel can be easily found without exact measuring of the weight.

The term "robust" was introduced into statistics in connections with "bad" observations (outliers) which ruin the standard mean values, least square analysis, regression and variance/covariance analysis. The mean is not robust to outliers, whereas the median is robust. Therefore, switching from quadratic (least square) smooth optimization to non-smooth optimization principles for long-tailed data leads to robust statistical decisions. In general decision theory under uncertainty, the robustness is concerned with a proper representation of uncertainty and its interactions with decisions. This includes the choice of proper sets of feasible solutions and their performance indicators from socio-economic, technological, environmental, and risks concerns. Robustness of solutions in security analysis can be achieved by a non-trivial adaptation of known STO tools and by developing new tools tailored to this analysis, in particular, by using the worst-case feasible distributions, i.e., similar to non-Bayesian robustness in statistics.

The main purpose of this talk is to analyze some promising approaches in this area. First of all, the talk revises known concepts of non-Bayesian robustness in statistics and STO, including integrated STO models with randomized decisions. It outlines also recent developments of STO tools, in particular Adaptive Monte Carlo optimization, for collective multiagent risk mitigation and risk sharing. They demonstrated the ability to assess robust solutions for numerous case studies involving spatio-temporal heterogeneous losses from exposures to multivariate endogenously generated extreme events.

Specific attention is paid to decision problems with several agents formulated as principal-agent or agency problems. They refer to a variety of situations where a principal-agent regulates performance of other agents in order to secure public goods. An important example is the current debates on regulations in financial systems towards their stable long term performance. Different concepts have been developed such as Stackelberg game, leader-follower models, mathematical programs with equilibrium constraints, stochastic games, Bayes-Nash games. Although principal-agent problems have game theoretical features, the use of game theory is rather problematic for practical implementations because of unrealistic assumptions about known preferences of all agents. Implicitly, these assumptions are also used in bi-level and more general mathematical programs with equilibrium constraints.

In addition, existing models primarily use deterministic equivalent formulations by replacing uncertainties with mean values. Often this requires multidimensional integrations producing degenerated responses of agents. Since these responses are used by the principal-agent, its objective and constraints functions become discontinuous already for linear objective and constraints functions of all agents. Solutions of such models are dramatically sensitive to slight variations of their parameters. We formulate robust versions of the principle-agent problem as non-Bayesian STO models and outline simulation-based solution procedures. We pay specific attention to decision problems in randomized strategies and to rather natural representations of feasible probability sets, in particular, for characterizing multivariate extreme events. A simple ”leader-follow” problem is considered to illustrate the concept of robust solutions in randomized strategies by using an analogy with probabilistic downscaling models.

Carbon Emissions Trading and Carbon Taxes under Uncertainties

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Keywords: emission, trading, robust solutions, verification, safety constraints, cost-effectiveness, decentralization

The idea of market-based carbon emissions trading and carbon taxes is gaining in popularity as a global climate change policy instrument. As it is well known, however, these mechanisms will not have a positive outcome unless their value reflects socioeconomic and environmental impacts and regulations. Moreover, the fact that they have various inherent exogenous and endogenous uncertainties raises serious concerns about their ability to reduce emissions.

In this presentation we introduce a simple stochastic model that allows the robustness of economic mechanisms for emission reduction under multiple natural and human-related uncertainties to be analyzed. Unlike standard equilibrium state analysis, the model shows that the explicit introduction of uncertainties regarding emissions, abatement costs, and equilibrium states makes it practically impossible for existing market-based trading and carbon taxes to be environmentally safe and cost-effective.

We discuss a computerized multi-agent trading system that may have a central role in dealing with long-term perspectives of emission reductions, their direct regulation, irreversibility, and *lock-in* equilibriums. Such a system can be viewed as a device for decentralized collective regulation of trades.

Decision Support for the Analysis of Food Security under Uncertainties

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Keywords: food security, uncertainties, safety constraints, system's balance, ex-ante (precautionary) and ex-post (adaptive) two-stage decisions

Following the definition of the UN Food and Agriculture Organization, the notion of food insecurity refers to limited or uncertain availability of nutritionally adequate and safe foods, or limited and uncertain ability to acquire healthy foods in socially acceptable ways. Within the limits of physical production potential, effective land performance and food security are largely determined by anthropogenic drivers and constraints, e.g., rural development, availability of infra-structure and agricultural technology, conditions on national and international markets.

Striving for food security must be accompanied by a clear grip of inherent risks and uncertainties. Current and future food availability and adequacy may be disturbed by inappropriate policy decisions, natural catastrophes and societal shocks, e.g., droughts, floods, earthquakes, epidemics, financial and political crisis. Thus, a major goal of food security research is to identify conditions ensuring stable balances between the food demand and provision under uncertainties, risks, possibly, of catastrophic nature.

This presentation illustrates some fragments from Land Use and Agriculture (LUC) program model applied for the analysis of rural development and agricultural production expansion in China and Ukraine, and confirms that for deriving robust performance of food systems it is also economically advantageous to find a proper balance between mitigation (precautionary) and adaptation (corrective) decisions to avoid or reduce the shocks and their impacts. This type of planning corresponds to the so-called two-stage optimization when strategic ex-ante decisions are supplemented by a set of adaptive ex-post adjustments.

An Empirical Analysis of Individual Heterogeneity Effect on Ambiguity Aversion

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Keywords: ambiguity, earthquake insurance, appraisal risk, maximin expected utility

In this study, I empirically investigate the influence of the ambiguity of insurance payment on the consumer's decision to purchase an earthquake insurance. Then, I examine the relationship between the ambiguity effect and individual characteristics.

Earthquake insurance can be helpful to repair or rebuild a damaged houses. However, purchase rate of earthquake insurance is low in Japan (only 17.2% households buy the earthquake insurance). One of the most important reason is ambiguity of insurance payment. It means the lack of knowledge on the earthquake insurance policy and insurance adjustment. Ambiguity of insurance payment stems from unclear criteria that the insurance adjuster will use to assess the damage from earthquake. This makes consumers feel concerned over the possibility that the claim is not paid as they expect. To examine the effect of such ambiguity, questionnaires were sent out by mail to 3,000 households in Joyo city, Kyoto in 2006. The questions are as follows.

(i) Imagine that you have a house worth 10 million yen and the other asset (e.g. cash, stocks, or land) worth 20 million yen. Assume that earthquake with a seismic intensity 7 on the Japanese scale will occur with probability of 5% in 25 years (or, 0.205% per year). If such earthquake happens, your house will be half destroyed (5 million yen loss) with 50% probability and completely destroyed (10 million yen loss) with 50% probability. What is the most you would be willing to pay for an insurance policy that will cover all damages due to earthquake?

(ii) Imagine that you have been offered a different policy that is identical to the previous one expect that there is about 1% (or 5%, 10%) unreimbursement risk. That is, there is a possibility with about 1% (or 5%, 10%) that your claim will not be paid in case of half collapse and only half of your claim will be paid in case of complete collapse. This risk is caused by the adjuster's too strict assessment. What is most you would be willing to pay for this probabilistic insurance?

To examine the influence of ambiguity of insurance payment, I analyze the data based on both the Expected Utility (EU) model and Maximin Expected Utility (MEU) model developed by Gilboa and Schmeidler (1989). MEU is the generalized expected utility model to deal with the ambiguity.

The main results of this paper may be summarized as follows. First, we have observed that people dislike probabilistic insurance: Most residents demanded more than 10% reduction in premium to offset a 1% appraisal risk. Second, we have demonstrated that such preferences are generally inconsistent with expected utility theory. Third, we have shown that the reluctant to buy probabilistic insurance is better predicted by the Maximin Expected Utility model. Forth, the perceived ambiguity is smaller in people who purchases earthquake insurance, have experienced earthquake loss on their houses than each correspondents. And it decreases with age education level.

Modeling Endogenous Technological Change

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Keywords: endogenous technological changes, increasing returns, uncertainties, environmental and safety constraints, earlier investments

The proper modeling of technological changes is decisive for the evaluation of the true socio-economic and environmental impacts of innovations and development policies. Traditional neo-classical models assume that technological innovations are key factors of long-term productivity, continuous economic growth and the prosperity of nations. However, on-going global changes, in particular, the pollution with potential catastrophic global climate changes, the increasing gap between the rich and poor, uncontrolled growth of settlements and their vulnerability, inspire great concerns about sustainable developments, equity and the welfare. Searching only for economic efficiency and growth may produce adverse impacts of innovations which are often impossible to properly represent in traditional models.

In many economic models, technological change is represented by exogenous variables, which improve efficiency and costs of technologies through time independently of policies and other economic variables. As a consequence, such models strongly advocate to postpone investments in new technologies until they became cheap enough, i.e., weight-and-see policies. In reality technological changes are endogenous. They are induced by various pressures and needs i.e., they can be affected by deliberate policies related to urgent socio-economic, environmental and safety issues. While models with exogenous technological changes ignore the necessity to invest in new technology in order to make this technology cheaper, the models with endogenous technological changes emphasize this necessity. Explicit modeling of endogenous technological changes with increasing returns and uncertainties radically offsets the rational for postponed investments with crucial policy implications regarding the timing of investments.

The aim of this presentation is to discuss methodological challenges involved in modeling of endogenous technological changes with increasing returns and uncertainties by using simplified fragments of so-called bottom-up models developed at IIASA. Realistic versions of these models usually have massive data sets and extremely large number of variables making it impossible to comprehend the interplay of different assumptions and their sensitivity. The discussed stylized versions allow in a simplified manner to indicate the main mechanisms and driving forces of these models.

Robust Optimization by Means of Fuzzy Linear Programming

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Keywords: robust optimization, fuzzy programming, necessity measure, optimization approach, satisficing approach

In the real world problems, we may face the cases when parameters of linear programming problems are not known exactly. In such cases, parameters can be treated as random variables or possibilistic variables. The probability distribution which random variables obey are not always easily obtained because they are assumed to be obtained by strict measurement owing to the cardinality of the probability. On the other hand, the possibility distribution restricting possibilistic variables can be obtained rather easily because they are assumed to be obtained from experts' perception owing to the ordinality of possibility. Then possibilistic programming approach would be convenient as an optimization technique under uncertainty.

In this talk, we review possibilistic linear programming approaches to robust optimization. Possibilistic linear programming approaches can be classified into three cases: optimizing approach, satisficing approach and two-stage approach. Because the third approach has not yet been very developed, we focus on the other two approaches. First we review the optimization approach. We describe a necessarily optimal solution as a robust optimal solution in the optimization approach. Because a necessarily optimal solution do not always exist, necessarily soft optimal solutions have been proposed. In the necessarily soft optimal solutions, the optimality conditions is relaxed to an approximate optimality conditions. The relation to minimax regret solution is shown and a solution procedure for obtaining a best necessarily soft optimal solution is briefly described.

Next we talk about the modality constrained programming approach. A robust treatment of constraints are introduced. Then the necessity measure optimization model and necessity fractile optimization model are described as treatments of an objective function. They are models from the viewpoint of robust optimization. The simple models can preserve the linearity of the original problems. We describe how much we can generalize the simple models without great loss of linearity.

A modality goal programming approach is briefly introduced. By this approach, we can control the distribution of objective function values by a given goal.

Finally, we conclude this talk by giving future topics in possibilistic linear programming.

Dynamic Lindahl Equilibrium under Uncertainty: A Model for Global Cooperation on Climate Change

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Keywords: Lindahl equilibrium, climate change, stochastic programming

Lindahl equilibrium is sometimes considered as an attractive framework to analyze cooperative agreements for climate change. However, the previous studies concern the static and deterministic models only. In this article we propose a definition of Lindahl equilibrium for a dynamic and stochastic model of global climate change. Such equilibrium is characterized by emission charges and compensations. At the equilibrium, the emissions charges cover the compensation payments, the world regions unanimously agree on the stochastic stream of global emissions, and the allocations are efficient (Pareto optimal).

We discuss the existence of Lindahl equilibrium and propose an iterative method for computation. We show how the equilibrium can be implemented in a decentralized way employing emissions trading. A variety of uncertainties may be considered, such as the impact of temperature increase, technology development, population growth, deforestation, etc. The approach is tested by developing and using a stochastic version of the RICE model (Nordhaus, Bover and Yang).

Multi-criteria Decision Support System for Siemianowka Reservoir under Uncertainties

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Keywords: stochastic reservoir management, Upper Narew, stochastic linear transfer function

Extreme events, such as floods or long drought periods, might become the most noticeable effects of climatic change. Variations in a hydrological cycle could have enormous impacts not only on the human economy but also on the ambient ecosystem. Therefore biodiversity protection and the conservation of valuable areas have recently become very important issues in water management politics. In the case of a river system the issue is manifested as a wide range of activities aimed at providing desirable water conditions at protected sites following the demands of existing ecosystems. In many areas freshets that are considered to be a serious threat to the economy and agriculture, has became an essential part of vegetation cycle, significantly increasing the biodiversity of the region. Narew National Park (NNP), Poland, is such an example. Because of the semi-natural character of the region, freshets do not cause losses but are necessary to preserve the environmental value of the region.

This paper presents a Multiple Criteria Decision Support System for the optimal management of the Siemianówka reservoir. The reservoir is localised on the Narew River upstream the NNP. The river system under considerations consists of a storage reservoir and a 100 km long River Narew reach, at which end the NNP is located. The goal of the work is to provide decision makers with a tool that would allow the safety of the NNP environmental requirements within the reservoir management policy to be included. An important issue is the competition between many water-dependent systems and agents, e.g., agriculture, energy, wetlands, for limited water resources. The proposed system allows a trade-off between different reservoir users to be found, including protected wetland ecosystems of the Narew Nation Park. Unobserved inflows play an essential role in the river water balance and are dealt with using rain-runoff modelling techniques. Taking account of weather forecast uncertainties and inherent errors related to the model structure is one of the most challenging tasks, as reservoir management actions have to be performed in advance. Precipitation forecasts are acquired in the form of 7 days-ahead predictions. In this paper we apply a stochastic weather forecast emulator of the European Centre for Medium Range Weather Forecasts ensemble. The resulting inflow predictions consist of a number of possible scenarios. In addition, as the optimisation problem requires numerous realizations of the river model, a numerically efficient Stochastic Linear Transfer Function was applied to flow routing.

To find the optimal solution for all possible scenarios, the reservoir control problem was formulated in a stochastic manner. Optimisation was carried out for several criteria: wetland water requirements, agricultural, energy production, flood protection, fishery and reservoir storage. The goal was to achieve a desirable water management regime within the defined safety levels. These highly non-linear constrains were met through the minimisation of convex functions by solving a linear programming problem within a Multiple Criteria Analysis.

Risk Hedging Strategies under Energy System and Carbon Price Uncertainties – An Application of the Stochastic MESSAGE Model

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Keywords: risk hedging, energy system model, stochastic optimization, climate change, investments

The future development of the energy sector is rife with uncertainties. They concern virtually the entire energy chain, from resource extraction to conversion technologies, energy demand, and the stringency of future environmental policies. Investment decisions today need thus not only to be cost-effective from the present perspective, but have to take into account also the imputed future risks of above uncertainties.

This presentation will introduce a recently developed energy systems model with endogenous representation of above uncertainties. We employ stochastic optimization techniques within a system engineering model of the global energy system and implement several alternative formulations of the optimization problem (e.g. risk-constrained cost minimization, cost-constrained risk minimization) as well as different risk measures (e.g. downside risk, β-CVaR).

Through a series of sensitivity analysis we aim to identify salient characteristics of least-cost risk hedging strategies that are adapted to considerably reduce future risks and are hence robust against a wide range of future uncertainties. We observe significant changes in response to energy system and carbon tax uncertainties, in particular:

- higher short-to medium-term investments into advanced technologies,
- pronounced emissions reductions, and
- diversification of the technology portfolio.

From a methodological perspective, we find that there are strong interactions and synergies between different types of uncertainties. Cost-effective risk hedging strategies thus need to take a holistic view and comprehensively account for all (above) uncertainties jointly. With respect to costs, we find that modest risk premiums (or hedging investments) can significantly reduce the vulnerability of the energy system against the associated uncertainties. The extent of early investments, diversification and emissions reductions, however, depends on the risk premium that decision makers are willing to pay to respond to prevailing uncertainties, i.e. our modeling framework helps to understand how much risk can be avoided through which mechanisms and at what costs, but how much risk needs to be avoided remains one of the key policy variables.

Information Technology Investment Decision-making under Uncertainty

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Keywords: business value analysis, discounted cash flow, information technologies, return of investments, service-oriented architecture, real-options, business model dynamics, multi-criteria analysis.

The enterprises are turning to SOA for the cost-effective flexibility and enhanced usage of legacy IT. But the shift to SOA does not come easy and does not come cheap. Building an effective SOA platform requires tight integration between new and existing product categories, and it may require large investments for new products such as SOA repositories. In the early stages of an SOA, limited ROI is achieved mainly from the creation of services from existing applications. It is not unusual for some organizations to experience negative ROI compared to conventional software development methods because additional investment may be required to achieve reusable services and to build an SOA infrastructure. IT flexibility becomes a reality once there are enough services in an SOA to stimulate extensive internal and external services reuse and consumption. But, the largest business value of SOA, e.g., business agility and competitive advantage, is only gathered once the business starts to use services to orchestrate processes within the enterprise and choreograph processes between enterprises. Unlike traditional technology investments that tend to be implemented enterprise-wide in big-bang fashion, SOA is realized over a long time horizon through many distinct projects distributed throughout an organization. And, in addition to the uncertainty associated with future service reuse, quantification of the soft benefits of SOA is often problematic.

Therefore, the conventional valuation methods, such as Net Present Value (NPV), need to be combined with concepts from Real-option theory and other modern techniques to reflect SOAs long-term strategic investment nature, the inherent uncertainty and the managerial discretion involved in SOA investment. These and some other emerging value-based analytical techniques, showing a promise, have started to be developed extensively under the umbrella concept of Business Value Analysis (BVA). BVA attempts to analyze the factors and forces that will shape the future instead of trying to forecast the future. It brings together methodologies that extend DCF (Discounted Cash Flow) and other traditional financial analysis techniques to include intangibles and other factors common to the digital economy. BVA includes the following techniques: Real-Options, Intellectual Capital, Business Model Dynamics, Synthetic Markets, Multi-criteria analysis, Ratio methods, and Portfolio theory.

However, BVA is not yet a wholly integrated analysis technique and the theoretical foundation for it needs to be strengthened. Furthermore, more work needs to be done on the practical side. Properly implemented with supporting IT/SOA, BVA has the potential to lead to better investment decisions and business results. Thus, the research reported in this paper attempts to respond to the following BVA challenges while implementing SOA: (1) clear, logical analysis of non-quantified and intangible factors; (2) quantifying the value of flexibility, options, and choices; (3) metrics and analysis to manage projects during and after deployment to capture value, control risks, and capitalize on opportunities.

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Multivariate Conditional Value-at-Risk as a Risk Measure

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Keywords: multivariate risks, risk measures, optimization, column generation technique, experimental analysis

The paper introduces a new scalar risk measure called Multivariate Conditional Value-at-Risk (MCVaR) for multivariate risks which are perfect substitutes. MCVaR in general is not coherent and slightly differs from the Conditional Value-at-Risk (CVaR) typically used in a multivariate setting. However, that difference allows one to efficiently solve real life optimization problems through the column generation technique, which are not tractable by the standard CVaR optimization model due to a huge number of scenarios. The results of computational exercise are presented and discussed.

Optimal Structural Control under Stochastic Uncertainty

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Keywords: optimal control under stochastic uncertainty, robust optimal regulators, open-loop feedback control, stochastic Hamiltonian, H-minimum control, stochastic 2-point boundary value problems

In order to omit structural damages and therefore high compensation (recourse) costs, active control techniques are used in structural engineering, [2]. The structures usually are stationary, safe and stable without considerable external dynamic disturbances. Thus, in case of heavy dynamic disturbances, such as earthquakes, wind turbulences, water waves, etc., which would cause large vibrations, additional control elements are installed in order to counteract [1] heavy applied dynamic loads.

The structural dynamics is modeled by means of a system of first order differential equations with random dynamic parameters, random initial values and a control force vector depending on an input control function $u(t)$ for the state vector $z = z(t)$ (displacement vector q and time derivative $\dot{q}$). Robust optimal feedback controls are determined in order to cope with the stochastic uncertainty involved in the dynamic parameters, the initial values and the applied loadings. In practice, the design of regulators is directed often to reduce the mean square response, i.e. the displacements, of the system to a desired level within a reasonable span of time, see e.g. [1, 3].

While the actual time path of the random external load is not known at the planning stage, we may assume that the probability distribution or at least the moments under consideration of the applied load and other random parameters are known, see [2]. The performance of the resulting structural regulator problem under stochastic uncertainty is evaluated by means of a convex quadratic cost function $L = L(t, z, u)$ of the vector $z = z(t)$ of displacements and the control input vector $u = u(t)$. The problem is then to determine a feedback, or an open-loop feedback control law minimizing the expected total costs, cf. [3, 4].

Necessary and sufficient optimality conditions for the resulting stochastic optimal regulator problem may be formulated in terms of the *stochastic Hamiltonian* of the control problem. Here, a canonical (Hamiltonian) Two-Point Boundary Value problem with random coefficients is obtained for the computation of an optimal (open-loop) feedback control law. The optimal regulator parameters $V^* = V^*(t)$ of the control law may be represented by means of a *H-minimum control* $\widetilde{V}^*$ which is obtained by solving a certain *finite dimensional stochastic programming problem.* The related canonical system of differential equations with random parameters for the optimal state and co-state trajectory $(z^*, y^*) = (z^*(t,\omega), y^*(t,\omega))$ may be solved numerically i) by means of discretizations of the underlying probability distribution of the random parameters. As further possibilities, ii) approximations based on Taylor expansions of the occurring expectations and iii) *partial or inner linearization* are discussed.

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Semi-supervised Clustering with Kernel Functions

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Keywords: semi-supervised clustering, kernel function

Semi-supervised learning has attracted researchers' attention and many works have been done up to now. In particular, a standard book by Chapelle *et al*. [1] shows a paradigm of *semi-supervised learning* based on a probabilistic framework and using support vector machines [5]. However, this framework seems to be smaller than expected, since the concept of semi-supervised clustering is not yet established. More concretely, agglomerative algorithms and nonhierarchical clustering algorithms such as crisp and fuzzy c-means are not based on a probabilistic model. These methods should have semi-supervised algorithms, since they are useful in many applications. In other words, the concept of semi-supervised classification is of limited usefulness without such semi-supervised clustering algorithms.

With the above motivation, we show a number of different methods in this paper:

1. Simple agglomerative algorithms of semi-supervised clustering based on a weighted graph model in which the single linkage, complete linkage, and average linkage are used [3].
2. Kernel-based agglomerative algorithms [2] of semi-supervised clustering with pairwise constraints where the Gaussian kernel functions [4] should be used.
3. Crisp and fuzzy c-means algorithms for semi-supervised clustering that used either the pairwise constraints or reference clusters.

By these approaches, we try to establish the concept of semi-supervised clustering without a probabilistic framework. As a result applications of clustering will become broader than ever.

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Robust Decisions under Risk for Imprecise Probabilities

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Keywords: decisions under risk, robust optimization, tail means, CVaR, linear programing

Several approaches have been developed to deal with uncertain or imprecise data in optimization problem. The approaches focused on the quality or on the variation (stability) of the solution for some data domains are considered robust. The precise concept of robustness depends on the way the uncertain data domains and the quality or stability characteristics are introduced. Typically, in robust analysis one does not attribute any probability distribution to represent uncertainties. Data uncertainty is rather represented by non-attributed scenarios. A conservative notion of robustness focusing on worst case scenario results is widely accepted and the min-max optimization is commonly used to seek robust solutions. The worst case scenario analysis can be applied either to the absolute values of objectives (the absolute robustness) or to the regret values (the deviational robustness).

In this paper we focus on robust approaches to decisions under risk where the expected outcome is maximized but the probabilities are known imprecisely. Assume that the probabilities may be affected by perturbations varying within given intervals. Note that the probabilities although varying independently they must total to 1. We are interested in the optimization of the worst case expected outcome with respect to the probabilities perturbation set. For the case of unlimited perturbations the worst case expectation becomes the worst outcome (max-min solution).

We show that the robust solution for upper bounded probabilities with proportional upper limits on perturbations of probabilities becomes the tail β-mean known also as the conditional value-at-risk (CVaR) with an appropriate tolerance level β. For proportional upper and lower limits on weights perturbation the robust solution may be expressed as optimization of appropriately combined the mean and the tail mean criteria. Finally, a general robust solution for any arbitrary intervals of probabilities or probabilities perturbations can be expressed with optimization problem very similar to the tail β-mean and thereby easily implementable with auxiliary linear inequalities.

Modelling and Processing of Uncertainty in Civil Engineering

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Keywords: data and model uncertainty, fuzzy random variable, fuzzy stochastic analysis

Numerical simulation of structures in the field of civil engineering is usually characterized by data and model uncertainty. Data uncertainty is uncertainty in the input variables of the numerical simulation, whereas model uncertainty is uncertainty in the underlying model of the simulation induced by uncertain parameters. Basically, uncertain data and parameters may be classified into fuzzy, random, and fuzzy random data and parameters, respectively. Realistic numerical simulation of civil engineering structures requires a precise distinction and an adequate modelling of those uncertainty phenomena with respect to their sources.

Fuzzy data result from the impossibility of an accurate characterization of single observations or information. Random data result from the variation within a sample of single observations. Fuzzy random data occur if a sample of fuzzy data is observed. Processing of those uncertain data and parameter succeeds with the help of fuzzy stochastic structural analysis. Fuzzy stochastic structural analysis is constituted by the mapping of fuzzy random input variables onto fuzzy random result variables, whereas the mapping model represents the computational model. Therewith, a hierarchical three-loop computational model is constituted, which may be organized in two different variants. The first variant is based on the bunch parameter representation of fuzzy random variables. Fuzzy analysis in the form of α-level optimization establishes the outer loop, stochastic analysis the middle loop, and the deterministic fundamental solution the inner loop. The second variant utilizes the increment representation of fuzzy random variables. In comparison with the first variant, the sequence of stochastic analysis and fuzzy analysis is changed. By means of fuzzy analysis, it is possible to map fuzzy input variables onto fuzzy result variables. The fuzzy result variables of a fuzzy analysis may be found by applying the extension principle. Under the condition that the fuzzy variables are convex, however, α-level optimization is numerically more efficient. In case of non-convex fuzzy variables, the generalized α-level optimization has to be applied. By means of stochastic analysis, random input variables are mapped onto random result variables by applying e.g. Monte-Carlo techniques. The deterministic fundamental solution represents an arbitrary computational model, e.g. a finite element model. No special properties of the applied computational model, such as linearity, monotony or convexity, are presupposed. The aforementioned two variants of fuzzy stochastic structural analysis enable safety assessment of structures under precise distinction of the different kinds of uncertainty.

The principal approaches will be illustrated by means of a number of model problems out of the field of civil engineering in order to show the significance and the applicability of the methods.

Evaluation of Portfolio of Financial and Insurance Instruments – Simulation of Uncertainty

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Keywords: catastrophe bonds, simulation, Vasicek model, analysis of risk

The increasing number of natural catastrophes leads to severe losses for agricultural and other production, in infrastructure and individual property. These losses also generate problems with financial stability of insurance enterprises. The insurance industry face overwhelming risks caused by natural catastrophes, e.g. losses from Hurricane Andrew hit 30 billion $ in 1992. The single event, e.g. earthquake or hurricane, could result in damages of $ 50 – $ 100 billion. Classical insurance mechanisms, like insurance premiums and funds, may not be sufficient in such cases because of dependencies among sources of losses, huge values of damages, problems with adverse selection and moral hazard. Additionally, the primary insurers rely on classical reinsurance markets. In the case of catastrophic events, reinsurers might not have sufficient capital. Therefore traditional modelling using central limit theorem and insurance theory of risk is not adequate. To cope with dramatic consequences of such extreme events integrated policy that combines mitigation measures with diversified ex-ante and ex-post financial instruments is required. Without proper policies the natural catastrophes will increase long-term consequences for societies and economy of many countries, especially poor ones. Keeping in mind that daily fluctuations on worldwide financial markets reach tens of billion $, securization of losses (e.g. in the form of so called catastrophe bonds) may be seen as one of such financial instruments.

Cat bonds were introduced in 1992, and become wider known in April 1997, when USAA, an insurer from Texas, initiated two new classes of cat bonds: A-1 and A-2. The cat bond market in year 2003 hit a total issuance of $ 1.73 billion, a 42% increase from 2002's record of $ 1.22 billion. There is one important difference between cat bonds and other financial instruments. The premiums from cat bond are always connected with additional random variable, i.e. occurrence of some natural catastrophe in specified region and fixed time interval. Such event is called triggering point. For example, the A-1 USAA bond was connected with hurricane on the east coast of USA between July 15, 1997 and December 31, 1997. If there had been a hurricane in mentioned above region with more than $ 1 billion loses against USAA, the coupon of the bond would have been lost. As usually, the structure of payments for cat bonds depends also on some primary underlying asset. In case of A-1 USAA bond, the payment equalled LIBOR plus 282 basis points. The cash flows for catastrophe bonds are managed by special tailor-made fund, called a special-purpose vehicle (SPV).

In this paper we discuss the model of portfolio which consists of a few layers of insurance and financial instruments, like catastrophe fund, catastrophe bonds, governmental help, etc. We use approach based on neutral martingale method and simulations. We price the catastrophe bond applying Vasicek model used for zero-coupon bound under assumption of independence between catastrophe occurrence and behaviour of financial market. Obtained pricing formula is then applied in simulations. The mentioned portfolio should be optimal in some way, i.e. it should fulfil needs of both insureds and insurers. In order to achieve ”fairness” for both insurer and insureds, we limit the probability of insurer bankruptcy and the probability of overpayment for insureds. We discuss the effects of uncertainties which arise from estimation of rare events with serious, catastrophic consequences like natural catastrophes. Therefore there is a need to take into account possible errors in estimation, e.g. applying approach based on confidence intervals. These intervals may also incorporate expertise knowledge to overcome lack of precise data.

Possibilistic Modeling of Engineering Uncertainty

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Keywords: possibility theory, possibilistic methods, engineering uncertainty, design optimization

The implementation of possibilistic modeling for engineering uncertainty will be shown in this work. The models constructed will then be used in uncertainty analysis of structural example in the mechanical engineering field. These models can then be used for not only the uncertainty analysis but also to find the optimal design using reliability-based design optimization.

Uncertainty is categorized in two categories: aleatoric uncertainty due to randomness and epistemic uncertainty due to lack of information. This document will deal exclusively with the latter, where standard methods using probability have shown limitations. Methods based on the possibility theory framed by Zadeh, Dubois, Prade and others are well suited for describing epistemic uncertainty. Possibilistic models describe uncertainty with a membership function varying from 1 (fully possible) to 0 (impossible). Further, possibilistic models are discretized into stacks of intervals at a certain possibility levels. The calculation method uses interval analysis at these levels to calculate the possibilistic system response. As lack of information at early development stages and in the form of no or little statistical data is inherent in engineering design, possibilistic modeling will be demonstrated. In order to analyze such uncertainty in engineering with finite element analysis, computer fluid dynamics, or even analytically, one must first be able to quantify the uncertainty.

Possibilistic models can be constructed using statistical data as well as expert knowledge. In this work the uncertain models of engineering uncertainty were created using a small of number probes. These were then expanded through knowledge of the manufacturing process as well as known and expected property distributions. The procedure for the creation of possibilistic models of system parameters will be thoroughly introduced. This will be demonstrated on the nondeterministic mechanical and geometrical properties of the example.

The modeling methods introduced will then be shown on a structural mechanical engineering example. The mechanical response of a truss structure is calculated using finite element analysis with uncertain material and geometrical properties. First, the ability of possibilistic methods to analyze the uncertainty of a structural system will be shown. The possibility of failure due to mechanical criteria (i.e. stress, displacement constraints) is calculated with the uncertain system parameters. Further an efficient design optimization is carried out using possibilistic restraints. The optimal design shall be not only light but with acceptable possibility of failure. For this the quality of the possibilistic input models is crucial. Therefore, differences in the modeling approaches and their effect on the results will be discussed.

Integrated Modeling Framework to Assess and Mitigate Nitrogen Pollution from Agriculture: Concept and Case Study for China

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Keywords: agricultural intensification, nitrogen compounds, uncertainties, environmental indices, production allocation, robust pollution mitigation

Anthropogenic activities to fix atmospheric nitrogen have increased 10-fold since preindustrial times, i.e., from about 15 Tg N yr-1 in 1860 to about 156 Tg N yr-1 in the early 1990s. The largest portion of this fixed nitrogen is used as fertilizers. Applied to soil, fixed nitrogen is dispersed into the environment and cascades through diverse environmental pools. The most important pathways of nitrogen loss to the environmental are atmospheric emissions of NH3, N2O and NO, and leaching to groundwater or surface water. Nitrogen fixation is expected to further increase in the future, as demand on agricultural products will continue to rise. Much of this accelerated N cycle can be expected for Asian regions, where population numbers continue to increase and production technology is readily available. A remarkable increase in the production of agricultural products has indeed been observed over the last years in China. Due to its size (one fifth of the global population) as well as its rapid economic growth China is of global importance.

In this talk, we discuss problems inherent to modeling and estimating spatially-explicit current and future nitrogen fluxes from agriculture to the environment in China. We compare a number of available estimates for these fluxes and observe considerable differences and uncertainties, which can be attributed to the respective methodologies, modeling resolutions, technical parameters, or data availability. Instead of precise assessment of emission fluxes, we propose to use robust indicators to derive conclusions about the environmental burden from agriculture. These indicators may assist in guiding production allocation and expansion accounting for local constraints in such a way that both the increasing demands for agricultural products and the consideration of the environment are met. The indicators comprise of ammonia and nitrous oxide emissions and nitrate leaching. These variables do not necessarily complete the nitrogen balance however the estimates are consistently derived over all of China applying a stochastic and dynamic livestock and crop production model analyzing agricultural developments in China until 2030. The approach, applied here for China as a case study where a homogeneous set of input data is available over a large area, may likewise be used for agricultural planning in other world regions.

Optimal Design and Sensitivity of Large Spatial Trusses under Uncertainty

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Keywords: optimal robust design, large scale trusses, stochastic uncertainty, sensitivity

Recently, civil works are modelled not only for practical purposes, but they stand also for improvement, progress, aesthetics and prestige. One trend moves towards higher and higher buildings. But with its height, not only the monumentality and impressiveness rise, but also the sensitivity with respect to applied loads increases, and external influences become more crucial.

Because of that, this paper deals with the study of the change of the design and the robustness in dependence of the height of the structures. Using the first collapse theorem, the necessary and sufficient survival conditions of an elasto-plastic structure consist of the yield condition and the equilibrium condition.

The basis for our consideration is provided by a spatial n-storey truss which will be increased successively, and which is affected by applied random forces. Taking into account these random model parameters, we get a stochastic structural optimization problem which cannot be solved using the traditional methods. Instead of that, appropriate (deterministic) substitute problems are formulated. Here, the recourse problem will be formulated in general and in the standard form of stochastic linear programming (SLP). After the formulation of the stochastic optimization problem, the recourse problem based on discretization (RPD) and the expected value problem (EVP) are introduced as representatives of substitute problems. The resulting (large) linear programs (LP) can be solved efficiently by means of usual LP-solvers. Several numerical results are presented.

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