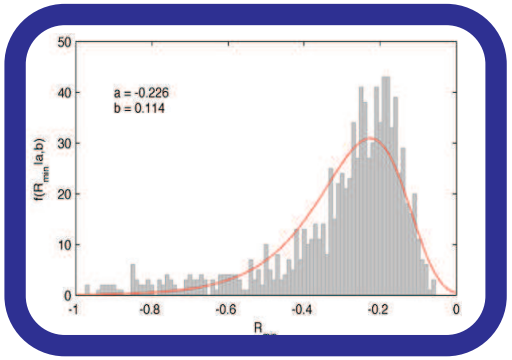
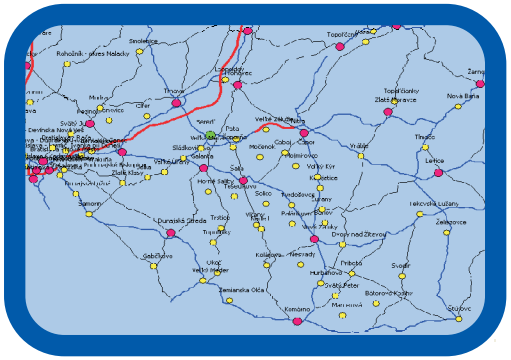
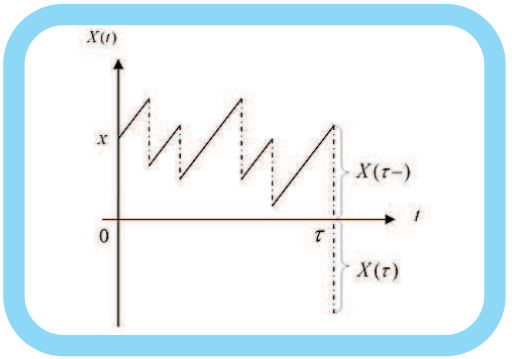
Department of Mathematical Methods and Operations Research

FACULTY OF MANAGEMENT SCIENCE AND INFORMATICS | UNIVERSITY OF ŽILINA







Department Profile

Subjects of teaching:

- Basic mathematical subjects (Algebra, Matematical Analysis, Graph Theory, etc.)
- Optimization of transport networks, Geographic Information Systems
- Simulations of transport networks, Data Structures
- Multimedia Information Systems, Computer Graphics
- Expert Systems, Artificial Intelligence
- Cryptography, Information Theory, Games Theory, Computer Typography, Open Source, Unix
- MSc. Projects

Science and research activities:

- Research projects in the field of optimization, simulation and operations research
- Cooperation with businesses and universities in Slovakia and abroad
- The organization of the international conference "Open Source in education, research and IT solutions" in cooperation with SOIT.

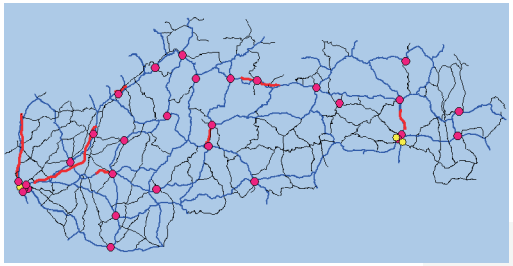
Optimization of transportation networks

Basics of optimization methods

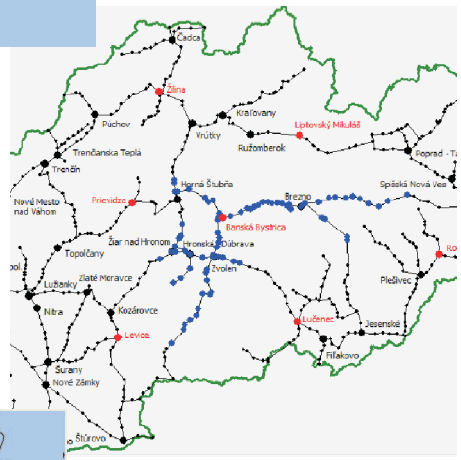
Advanced optimization techniques

Practical examples of solved problems:

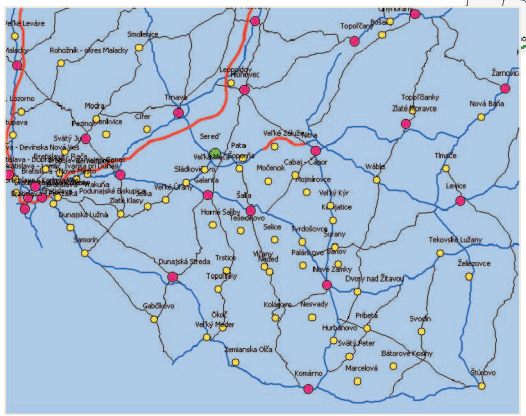
- Medical emergency centres location
- Marshalling yards location
- Optimization of intersections
- Warehouse placement



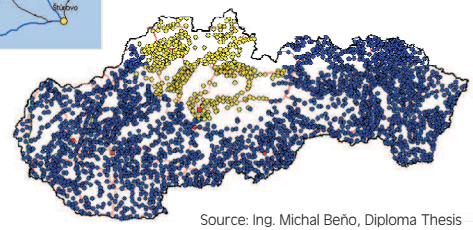
Source: Ing. Michal Kukuča, Diploma Thesis



Source: Ing. Jaroslav Jekkel, Diploma Thesis



Source: Ing. Michal Kukuča, Diploma Thesis



Source: Ing. Michal Beňo, Diploma Thesis

Simulation of transportation networks

Discrete simulation
- Rail transport
- Road transport
- Manufacturing processes
- Container terminals

Continuous simulation

Simulation tools

Source: Villon Simulation Tool

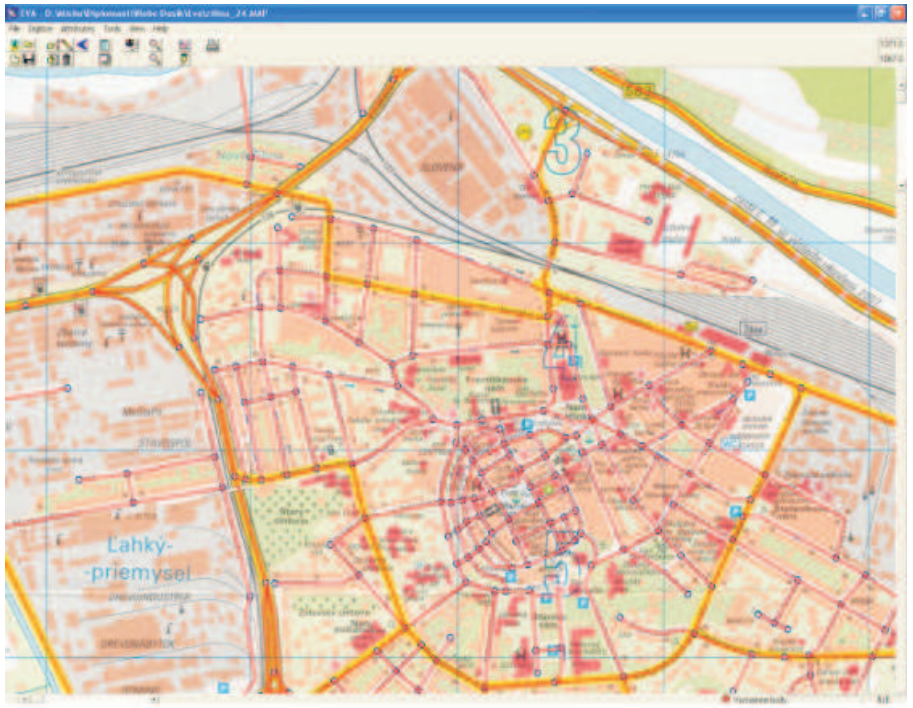
Geographic Information Systems

basis for optimization and simulation modelling

digitization (vectorization) of geographical data

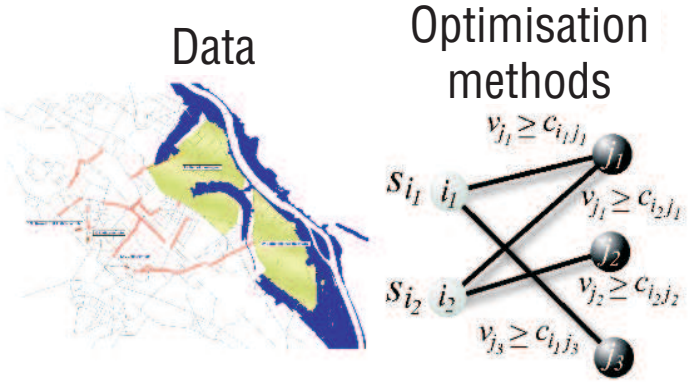
forecasting

analysis of changes
in time and space



Source: EVA - editor

Optimization methods and modeling



Retaining the competitiveness in the field of production and services providing requires management based on modern information technologies which enable providing an effective decision support on how to use available resources efficiently to achieve various goals.

Such decision support tools are necessary mainly if there are many feasible solutions available and it is not easy to choose the best ones or it is hard to find any solution which would meet the requirements at all.

From the viewpoint of designing a solution for a defined decision problem, the first step consists of creating a model expressing the desired objective and a mathematical expression of the options how to achieve the objective.

Using a suitable optimization algorithm integrated into a decision support tool, one or more feasible solutions can be found. The solutions are then provided to people responsible for decision-making in the particular field.

Optimization methods and modeling

Development of optimization methods

In the field of optimization methods we are seeking new possibilities of applying general optimization tools such as Xpress-IVE. Here, we have proposed efficient methods of approximate solving of location problems by their transformation to a case of set-covering problem that is less time consuming. In the field of specialized algorithms, we have suggested and developed new exact algorithms that enable effective solving of large-scaled location problems. Furthermore, we focus on development of new heuristic and evolution algorithms.

Applications of optimization techniques

We provide consultancy and expertise in applying optimization techniques in practical life. We have cooperated with companies like Slovenská Pošta (Slovak Post), Strabag, Železnice Slovenskej Republiky (Railways of the Slovak Republic), or Dopravný podnik mesta Žilina (City public transport operator in Žilina).

Public and private service systems

- Large private and public service systems concentrate providing customer services to service centers.Among examples of such systems, we can name emergency medical service system, fire brigade system, network of police stations, network of school facilities etc. The field of designing the structure of such systems has been one of our core research areas for a long time. Currently, we deal with a research project that has the following objectives:
  - To propose methods allowing considering various criteria of fairness in access to the provided service
  - To acquire new methods and techniques for solving public service system design problems with fair sharing criterion
  - Based on real examples, to evaluate the relationship between the service system effectiveness and the fairness level in access to services that the system provides

Optimization methods and modeling

Department has cooperated in solving optimization projects:

- Proposal of Transport services plan for the town of Púchov, Technical study for SAD Púchov, 2013, in cooperation with the Department of Road and Urban Transport FPEDAS
- Academic career of research and teaching staff at universities in Slovakia and possibilities of its optimization, IBS SLOVAKIA,Ltd., 2009
- Search algorithm for train and bus connections in timetables, EMtest Žilina, 2009
- Transport services plan for the town of Bardejov, Technical study, 2009, in cooperation with the Department of Road and Urban Transport FPEDAS
- Mass transport optimization for Road Projects: Application for N7 Nenagh - Limerick, Ireland, STRABAG Austria, 2007
- City public transport optimization - Martin and Vrútky, Technical study, 2005-6, in cooperation with the Department of Road and Urban Transport FPEDAS
- Suburban bus tours proposal - Prievidza, Technical study, 2005
- City public transport optimization - Trenčín, Technical study, 2005, in cooperation with VÚD Žilina
- City public transport optimization - Považská Bystrica, Technical study, 2005, in cooperation with VÚD Žilina
- Bus station optimization - Zvolen, Technical study, 2003
- System KASTOR - optimal bus tours in public transport (proposed in areas: Tábor, Uherské Hradiště, Uherský Brod).

Computer simulation

Computer simulation is a research method offering a wide range of opportunities to explore systems. It can be applied in various spheres of human life (industry, transportation, crisis management, health service and others) where it helps to save money, optimize the system, improve its effectiveness and protect human lives. Using experiments with a computer model of the existing system, we are able to analyse its features , predict its behaviour in various conditions.
Long-term experience of the Transportation Networks Department staff at the Faculty of Management Science and Informatics in modelling and simulation presents a solid foundation for research and development of simulation architectures as well as for implementation of complex simulation apparatuses.

Agent-oriented simulation

Our scientific and research activity is mostly concentrated to the agent-based simulation architecture. Our developed architecture ABASim (Agent Based Architecture of simulation models) provides tools for creating flexible simulation models of complex service systems such as transportation and logistic systems. A lot of models, successfully applied in business environment as well, is based on this architecture.

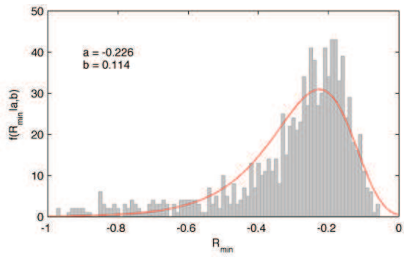
Computer simulation

Models of transportation and logistic systems

An example of successful simulation models developed based-on the architecture ABAsim is the Villon simulation tool a generic detailed microscopic simulation model of a logistic hub (e.g. railway station, company yard, container terminal, depot etc.). The simulation tool has been practically used to solve a large number of designing and optimization problems of transport logistics hubs in many European and Asian countries (Germany, Austria, Switzerland, China, etc.). Villon helps in designing the infrastructure and verifying station operation, in changing transport organization, increasing the production in production companies or in assessing the interaction of rail and road transport in hubs.

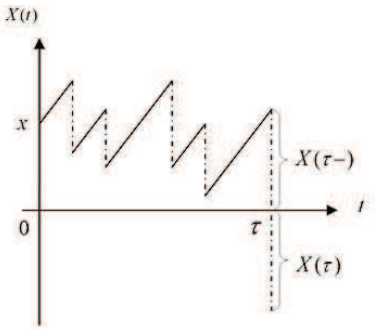
Furthermore, the research in our department is devoted to the development of a simulation tool for modelling movements and behaviour of pedestrians at the microscopic and macroscopic level. Modelling pedestrian movement is used mainly in designing transportation hubs and in the field of crisis management. It contributes to a greater comfort and safety of passengers.

Actuarial risk models and Risk theory



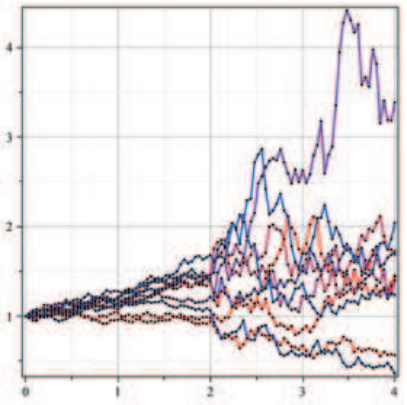
Actuarial risk models

In scope of the risk theory, we are concerned in the methods to determine the distribution of random variables describing the number of claims and amount of the individual severities, application of the indivudual and collective risk models to determine the probability of ruin, depending on the number and severities of the individual claims. In the context of this issue we deal with statistical analysis of extreme events.



Reinsurance

In the scope of the risk transfer analysis we focus on the optimization of the reinsurance chains. Its essence is the search for such composition of the reinsurance layers (within the obligatory and facultative reinsurance) that minimize the likelihood of the ruin. In determining the maximum possible claim we apply the method VaR (Value at Risk - VaR) and its refinement using the heavy tail distributions.



Recursions

When determining the total claim amount, which can not be stated by convolution of individual claims distribution, we replace these procedures by Panjér recursions. We modify these recursions for some specific types of division and are looking for their computer implementation using open source tools.

Science and research activities

Domestic Cooperation

- Matej Bel University, Banská Bystrica
- Pavol Jozef Šafárik University, Košice
- University of Economics, Bratislava
- Technical University v Košiciach, Faculty of Economics
- Slovak Environmental Agency
- Slovenská pošta (national post operator)
- CORAGEO, Ltd.
- Železnice Slovenskej republiky (management and operation of rail infrastructure)
- Železničná spoločnosť Cargo Slovakia (rail cargo operator)
- Dopravný podnik mesta Žiliny, Ltd. (city public transport operator)
- Spoločnosť pre otvorené informačné technológie, Bratislava (Slovak open source IT society)

International Cooperation

- University of Pardubice, Czech Republic
- VŠB-TU Ostrava, Czech Republic
- University of Economics, Praha, Faculty of management, Jindřichův Hradec, Czech Republic
- Red Hat, Brno, Czech Republic
- Centrum dopravního výzkumu, v.v.i., Brno, Czech Republic
- KVADOS, a.s., Ostrava, Czech Republic
- Silesian university Katowice, Poland
- TU Dresden, Germany
- TU Berlin, Germany
- TU Braunschweig, Germany
- HTW Dresden, Germany
- Molde University College, Molde, Norway
- TU Wien, Austria
- Univerzitet u Beogradu, Serbia
- ETH Zurich, Switzerland
- GISIG, Genova, Italy
- JRC Ispra, Italy
- Queen Mary University of London, Great Britain
- University of Cambridge, Great Britain