Applications

People in urban environment
Urban planning needs to consider a wide range of aspects, such as safety, accessibility and comfort. Many of these aspects can, and should be evaluated in an integrated fashion. We study the application of computational methods in multi-objective evaluation of urban environment functionality.

Nuclear power plant fire safety
For more than 20 years, we have carried out research on the fire safety of nuclear power plants by participating in both national SAFIR-programmes and international research programmes, and by carrying out contract research for industry and authorities. Some of the current public research topics include:
- fire defense-in-depth
- response by plant personnel and electrical systems
- simulation of large fire loads, such as pool and cable fires
- OECD NEA PRISME and PRISME2

Fire protection of structural elements
Fire safety engineering is used to produce justification for protective methods for structures under building fire conditions. The concept makes use of the measured distributions of the fire load densities and opening factors, parametric fire curves and event tree analysis, as well as comparisons with statistical data of real fires. The methodology enables the use of both passive and active protection methods and is applicable for timber, steel, etc. framed buildings.

Fire and evacuation safety of ships
We have strong expertise in fire and evacuation risk assessment of passenger ships. We use modern simulation tools to evaluate the alternative design of passenger ships, according to IMO MSC/Circ. 1002. The outcome is safe, comfortable and attractive ship with larger uniform spaces than what could be implemented following the conventional design rules.

Fire and evacuation safety of large buildings
VTT has more than 20 years of experience in applying the fire safety engineering (FSE) methods to performance-based design of large buildings. As a result, safe building can be constructed with reduced cost.

Aircraft impacts
We investigate the fires following an aircraft impact using CFD and FEM tools. Advanced experimental techniques, such as high-speed cameras with laser back lights, are used to determine the drop size and velocity distributions from high-speed impacts. Large-scale tests are used to validate the numerical simulations.

Fire and evacuation safety of passenger trains
VTT is experienced in assessing the evacuation safety of passenger trains in case of fire. The evacuation simulation procedure is applicable to various train scenarios with different geometries and features. The coupling of the FDS+Evac evacuation module with FDS fire simulation code makes it possible to take into account the effects of heat, smoke and toxic gases on the evacuation. Simulations provide a cost-effective method for fire and evacuation safety design of passenger trains.

Methods for fire and evacuation safety assessment

Fire simulation
VTT is one of the developers of the Fire Dynamics Simulator (FDS), a CFD-based computer code for the numerical simulation of fire phenomena. We are responsible for the development of thermal radiation and condensed-phase heat transfer and pyrolysis modules of FDS. Scientific novelty combined with the systematic verification and validation processes have made this open-source code the most widely used fire simulation code in the World.

Evacuation simulation
We develop and maintain the evacuation simulation module of the FDS code, called FDS+Evac. This open-source module allows stand-alone or coupled simulation of human evacuation and is the major tool for any performance-based assessment of human safety in buildings and transport systems. FDS+Evac contains an agent-based model for the human movement and decision making processes, considering e.g. way-finding and toxicological aspects.
Efficiency of fire safety systems

We use both experimental and simulation-based methods for the assessment of fire safety systems that are commonly used to ensure the safety of modern infrastructure, such as large buildings, ships, and tunnels. In cooperation with industry, we develop the simulation methods and use them to support applications such as high-pressure water mist, conventional sprinklers, and smoke management systems.

Human behaviour

We use experiments to increase our understanding of human behaviour during emergency situations. The results are used to model human reactions and decisions in safety assessment projects. Experimentally observed characteristics, such as specific flows through doors and corridors, walking speeds, and stair climbing speeds, are also used to validate the capabilities of the tools like FDS+Evac. We also develop algorithms for the modelling of exit selection, counterflow, and congestion-induced downfall.

Simulation of fire and structures

We have developed a software tool for coupling the CFD fire simulations with the FEM-based structural analysis. FDS2FEM tool transfers the fire simulation predictions for the surface heat flux and/or temperature to the time-dependent boundary conditions of the FEM-analysis.

Material fire safety

Atomistic simulation of materials

Reactive Molecular Dynamics (RMD) simulations are used to investigate the thermal degradation of polymers. The goals are to increase the theoretical understanding of flame retardancy and to support pyrolysis modelling. MD simulations are also performed to study metal oxidation and clay hydration processes.

Pyrolysis experiments and modelling

Understanding the thermal degradation of materials is an important part of material fire safety assessment. We use experiments and numerical simulations to evaluate the material performance, to investigate the effects of flame retardants and to explore the possibilities for structural optimization as part of product R&D.

For experiments, we use cone calorimeter, thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). Other commonly used assessment tools for material flammability and chemical composition are also available.

Modelling the heat transfer and pyrolysis in practical material requires determination of a large number of material specific parameters. We have developed both direct and optimization-based methods for the pyrolysis model parameter estimation, including the Pyroplot tool.

Performance of electrical cables

VTT has developed a unique experimental apparatus for the investigation of flame spread on cable (and other cylindrical objects) at elevated temperatures. When combined with small and bench-scale experiments and simulations, the new method can be used to assess the performance of electrical cables in fire conditions.

Fire safety of composites

The performance of new composite materials and structures can be evaluated using a wide range of methods, ranging from flammability tests to overall performance evaluation of complete structures. We have developed advanced simulation tools that combine fire and pyrolysis modelling (CFD) to structural analysis using FEM.

Risk analysis

Quantitative fire risk analysis

Quantitative risk analysis combines the probabilities of events to their consequences. We use Monte Carlo simulations to determine the likelihood of critical consequences. Our tools, such as the Probabilistic Fire Simulator (PFS), have been developed in the context of nuclear power plant fire safety, but have found applications in many other fields of fire safety engineering.

The level of acceptable risk is usually based on the statistics of the past incidents and political decisions to change the situation. We help authorities to specify what can be tolerated by a society and how to measure the impact of their decisions.

Operation time modelling

The efficiency of rescue and crisis management organizations can be evaluated using the Stochastic Operation Time Model. This model allows us to estimate the development of available resources by considering the distributions of individual operation times, inter-organizational communication needs and possibilities for additional delays. It has been used to evaluate the performance of nuclear power plant fire services and city fire service in cases of large railway fires.

Fire service impact and strategies

Research results can be used to measure the impacts of municipal fire services and the efficiency of the means to reduce residential fire deaths. We support the authorities when they are making strategic decisions on the allocation and distribution of resources in fire services and other first responders. We promote the use of numerical simulations in fire investigation.