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FRAUNHOFER INSTITUTE FOR HIGH-SPEED DYNAMICS, ERNST-MACH-INSTITUT, EMI

SOLUTIONS FOR URBAN RESILIENCE

Publishing notes

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Who we are

Fraunhofer EMI is an institute of the Fraunhofer-Gesellschaft, Europe's largest application-oriented research organization.

A distinctive feature of the institutes and research units of the Fraunhofer-Gesellschaft is their scientific excellence arising from their integration into the academic research landscape while networking well with industry. At this interface, we conduct basic preliminary research but also system development.

We have specialized in investigating physical-technical processes in materials, structures and components as they occur, for instance, during crash or impact.

Our mission

In our business units Security, Defense, Automotive, Space and Aviation, we aspire to offer first-class research services and cutting-edge technology to our customers from industry and the public sector. For this achievement, we focus on solutions for safety and security, reliability and **resilience**.

We derive our scientific strength and unique characteristics from being a one-stop source offering the combination of high-speed dynamics in experiment, modeling and simulation as well as engineering methods and technology.

Our service offer

We distinguish ourselves by in-house development of testing facilities, measuring instruments, sensors and software as well as by our own workshops, a high percentage of technical staff and a good mixture of senior scientists and PhD students. Thereby, we are able to flexibly adjust to individual requirements.

What we offer

In our business unit Security, we work on engineering tools, methods and technologies for real-life applications to quantify as well as strengthen resilience. Our work encompasses ideas and solutions for all phases of the holistic resilience cycle. It focusses on helping to preserve critical functionality, ensure graceful degradation and enable fast recovery of complex systems when they witness a disruption.

Prepare

- Quantitative risk analysis for urban security
- Simulating complex adaptive systems behavior
- Auditing the process of system and product development
- Academic training in the field of risk analysis and technical safety

Prevent

- Software tools for urban resilience management
- Modeling of cascading effects in coupled infrastructure networks
- Analyzing and improving technical safety of complex systems

Protect

- Development of security concepts and protective measures
- Retrofitting methods for built infrastructure
- Testing and improving protective materials

Respond

- Damage assessment for disruptive events
- Quantitative resilience analysis
- Sensor technologies to support relief forces

Recover

- Efficiency analysis for security measures
- Smart software solutions for infrastructure operators

Photo: Fraunhofer EMI in Freiburg.

VITRUV – optimizing resilience of built infrastructure

The VITRUV tool offers unique risk analysis capabilities combined with a user-friendly intuitive graphical user interface to urban planners and architects.

The VITRUV software helps city planners with empirical risk analysis based on the comprehensive terrorist event database (TED) in detecting potentially threatened points in their urban area models. For each building, empirical frequency of hazardous events are shown as well as empirical consequences per event.

The tool is able to evaluate the quantitative risk using validated physical and engineering models. A fast assessment provides results for consequence evaluation of:

- Damage to persons (in buildings or open space)
- Structural damage (glazing failure or progressive collapse of buildings; traffic infrastructure)
- Economic damage (buildings; direct or indirect costs for traffic infrastructure)

For the evaluation of the structural damage, numerous predefined building types and uses are implemented. They provide construction details from a single family house up to a public transport terminal or a high-rise building and cover the majority of existing cities.

With VITRUV's countermeasures, it is possible for architects and city planners to increase the resilience of their urban areas significantly during the planning phase already. Therefore, VITRUV offers various kinds of building reinforcement with cost calculation:

- Security glazing
- Ductile concrete
- Highly reinforced concrete
- Enhanced masonry and strongly enhanced masonry

Required resources

VITRUV can be run on standard PCs or notebooks. Memory, CPU and graphics cards requirements depend on the urban area model sizes the user wishes to simulate. For typical applications, a memory of 2 GB is recommended as well as a CPU with at least 2 GHz and a graphics card with 128 MB.

Photo: Damage to a government building caused by the car bomb attack in Oslo on July 22, 2011.

The picture shows a screenshot of the VITRUV software tool which was used to analyze the most probable locations for an attack in the government quarter of Oslo comparable to the one that really happened as well as its damaging effects on the surrounding buildings.

IDAS – urban resilience management

The IDAS software tool supports decision-makers in considering and answering typical questions regarding security and resilience in urban areas. The application is based on the risk management process of the international standard ISO 31000:2009.

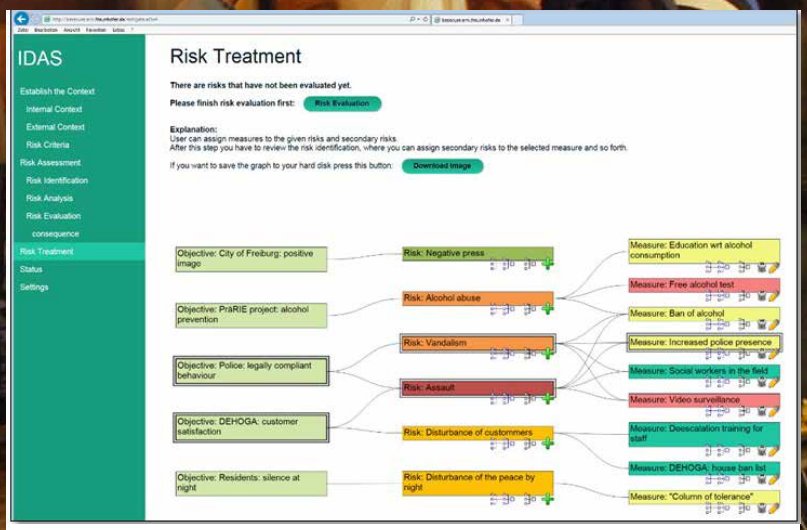
In the first phase of the risk management process, the relevant aspects of the context in which the risk management is pursued are gathered. On this occasion, the indicators can be recorded in the form of data sheets or time rows and then be analyzed. Then, the risks or chances are defined. In addition to the likelihood of occurence, the consequences are also recorded on an impact scale. As another key element, the objectives to be achieved have to be determined.

In the next step, IDAS guides the user to the risk identification, in which risks can be assigned to every single object. For the urban context, IDAS already suggests defined risks which are known from the past use of the software. In addition, the user can define risks himself. Based on the consequence scales and likelihoods identified and defined before, the identified risks can be analyzed in the next step, i.e., the expected probability of occurrence and the expected consequence are assigned. Afterwards, the identified and assumed risks are evaluated, while they are arranged and visualized in a risk matrix.

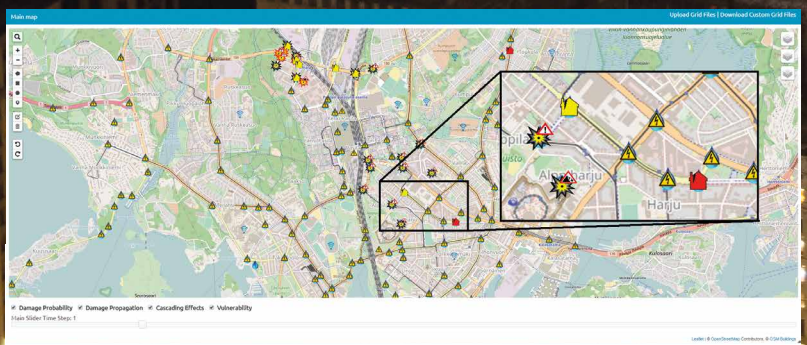
In the last step of the process, the handling of risks is addressed. To every risk, a measure can be assigned which diminishes the risk either because of the reduction of the probability of occurrence or because the consequences are minimized. In a graph, IDAS shows the coherence of the objects, risks and measures. Measures are evaluated based on their effect and duration of the effect. Because measures themselves can cause secondary risks again, IDAS permits assigning secondary risks.

In the application that has to be gone through iteratively, certain points in time can finally be set at which risks should be reconsidered and re-evaluated once more if necessary or to identify further measures.

Photo: The so-called "Bermuda triangle" in Freiburg is a crime hot spot. Relevant local stakeholders used IDAS to mitigate some of the problems.



The picture shows a screenshot of the IDAS software tool. The tool can be used by experts as a guided questionnaire to assess and manage risk and resilience within an urban context holistically.



The picture shows a screenshot of the CAESAR software tool that allows for simulating cascading effects throughout different networks of coupled infrastructure systems. Here, you can see the results of a random power outage in Helsinki on water and communication networks.

CAESAR – simulating coupled infrastructure networks

CAESAR is a coupled grid simulation tool, which computes cascading effects within grids and across grid borders to assess and enhance the resilience of critical infrastructure in urban areas. The overall target is to find optimized strategies for the mitigation of crisis impact on interconnected grids.

For this purpose, the CAESAR tool is connected to a dashboard, where the grids are mapped in terms of nodes and arcs in a georeferenced map. A crisis editor is used to define a damage event. Users can implement either threat-based damage resulting from specific events or generic damage understood as random failure of system components. Both types of damage scenarios may be defined as single ones or in combination with others. For every single event, an intensity can be set by choosing low, medium or high.

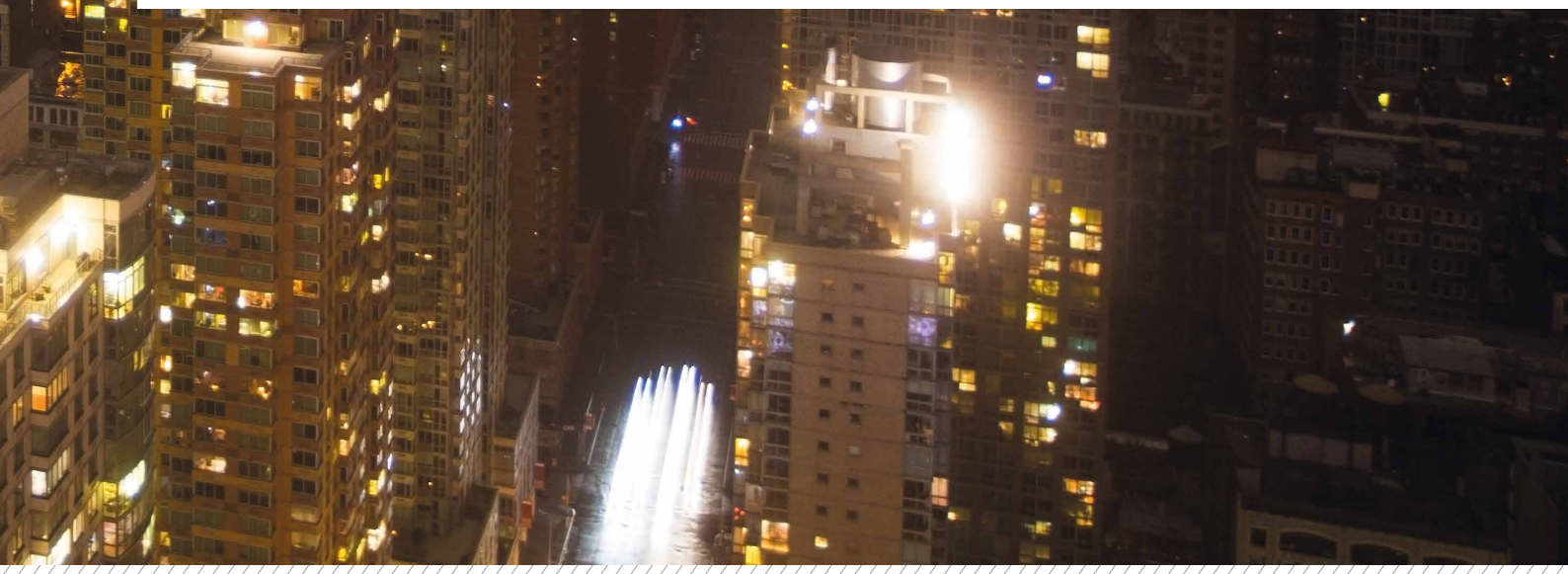
CAESAR computational steps:

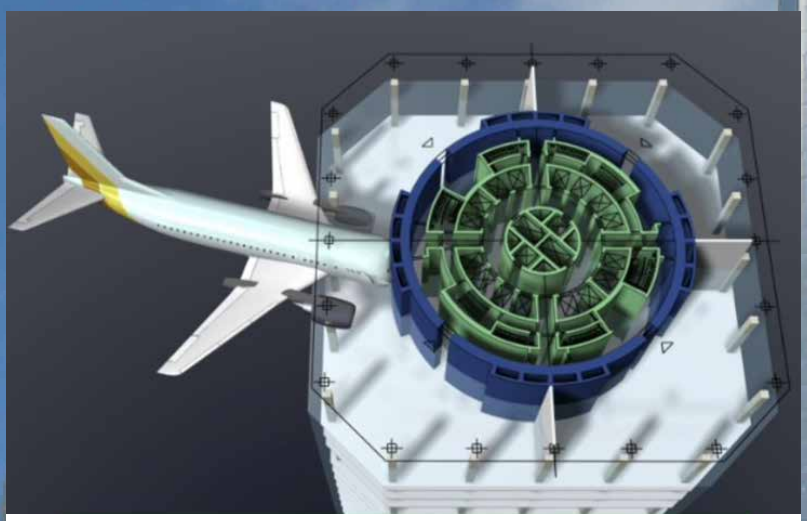
- Defining initial damage scenario
- Simulating propagation into the grid systems, e.g., via flow models, interface for third-party propagation model
- Propagating damage impact between different grids using specified physical models, georeferencing and defined dependency radius for interaction estimations
- Computing residual performance level of coupled supply grids after disruption
- Varying probabilities for sensitivity analysis to identify critical components
- Assessing resilience value R for the system
- Identifying and implementing mitigation strategies for critical components
- Rerunning the simulation
- Assessing resilience value RM for mitigated system

Mitigation strategies to apply to grid components:

- Structural strengthening
- Installation of redundant components
- Integration of an uninterrupted power supply

Photo: In October 2012, hurricane Sandy caused large-scale blackouts in Manhattan resulting in cascading failure of other infrastructure systems.





The picture shows a concept for designing a skyscraper that is able to withstand the impact of a passenger airliner and still provide critical functions – like power supply and evacuation routes – for people inside the building.

Protecting buildings and critical infrastructure

Fraunhofer EMI offers a wide variety of solutions and competences to protect buildings and critical infrastructure against disruptive events. A focus lies in the analysis of damages caused by explosive events, e.g., due to a terror attack, and the development of mitigation measures for these kinds of events.

Especially developed engineering codes allow the calculation of limits for the dynamic loading capacity of materials such as steel, reinforced concrete, masonry and glass, and the possibilities for reinforcement of these.

With the further development of ultra-high performance concrete and concept solutions for loading scenarios such as, for example, impact events in consequence of airplane crashes, the institute offers protection solutions to improve the residual load-carrying capacity of building structures.

Competences and solutions

- Development of concepts for protective design, e.g., security scraper, a skyscraper that is built around a secure core consisting of ultra-high performance concrete
- Polymer concrete, a material developed for absorbing energy and reducing the damage of impact loading and explosive events
- Consulting on the hazard potentials of explosives
- Identification of explosion damages through laboratory and free-field experiments as well as simulations
- Calculation and damage assessment of building components and buildings against explosion loads
- Damage analyses and design of security concepts for buildings and infrastructures regarding loadings such as hail or storms

Photo: One World Trade Center uses protection measures like an ultra-high performance concrete that was tested and qualified at Fraunhofer EMI.

How to work with us

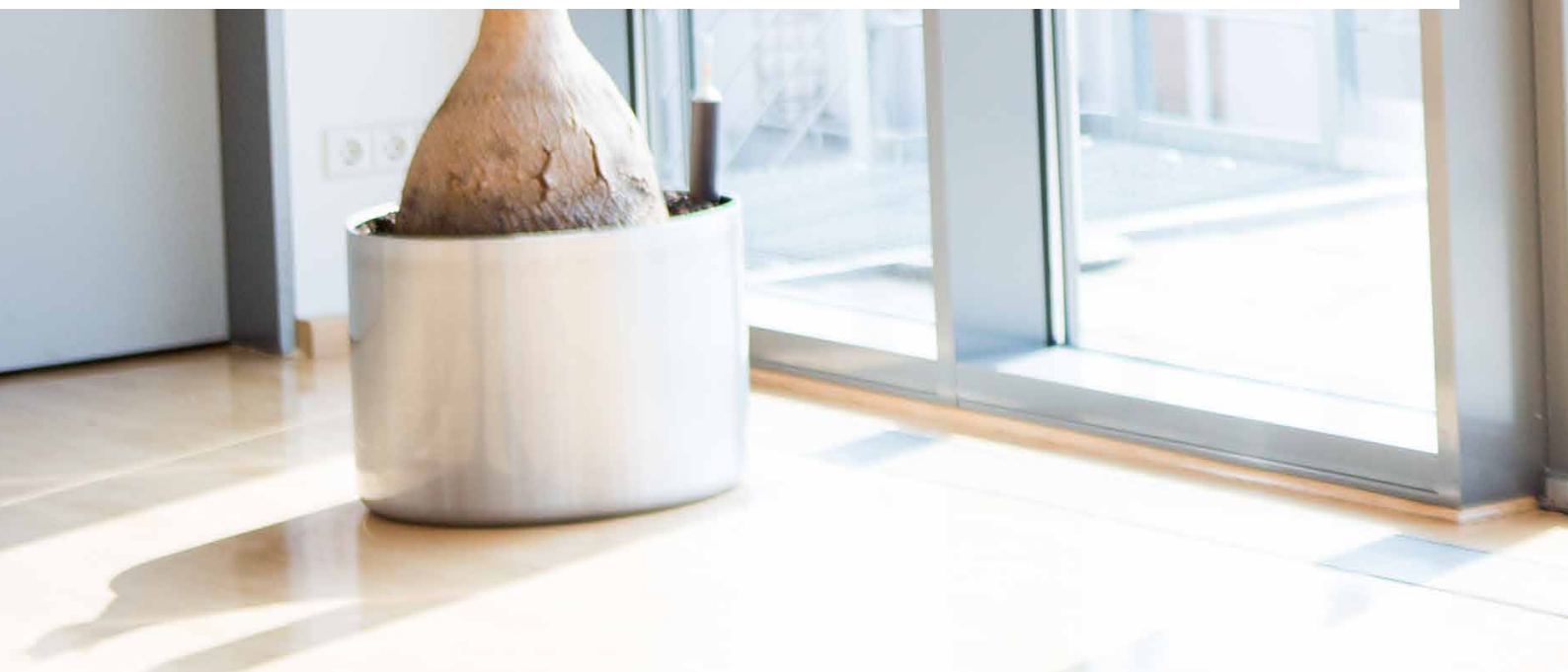
Research and development contracting
In the classical case of cooperation, you place your order with us for material testing, process optimization, safety and security analyses etc. in order to meet research and development demands of your enterprise. We create customer-oriented solutions adjusting to your particular needs and requirements.

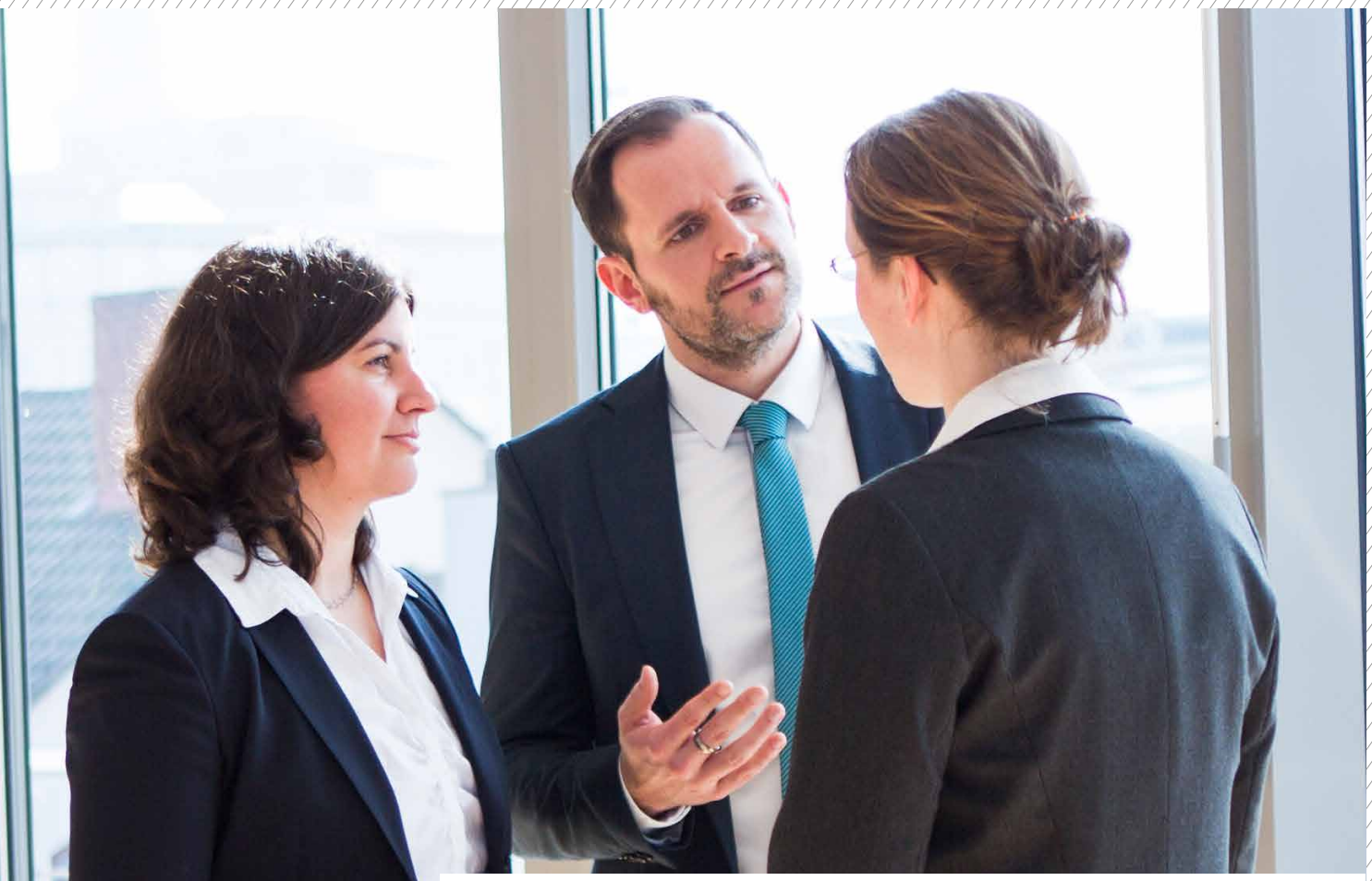
Strategic partnerships
This manner of long-term cooperation serves the basic preliminary research for a common goal as, for example, the development of new software, new testing methods, completely novel technologies or the employment of new materials. In cooperation with you, we explore the general feasibility of a concept, scopes of application and individual requirements.

PhD track for industry
PhD students carry out research at EMI on behalf of a company setting the topic. This very practically oriented way of graduating not only serves the productive exchange between research and application but also prepares junior scientists for their career in the industries.

Joint publicly funded projects
Together with you and other partners where required, we apply for resources from public research funding for a shared project concept, be it at the national or European level. These projects are mostly designed for a three-year period and enable us to develop solutions to problems in close collaboration.

Sustainability Center Freiburg
The cooperation between the University of Freiburg, the five Fraunhofer Institutes located in Freiburg and industry promotes the transfer of scientific developments to marketable and practice-oriented products and services. Network partners profit from the diverse expertise within the center and have easy and quick access to a broad knowledge base.





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