NEST
Pathfinder

PROTECTING INFRASTRUCTURE

MANMADE

Modern life could hardly survive without the transport, communication and energy supply infrastructures that everyone takes for granted. And yet, despite their importance, there has never been a rigorous theoretical framework available to characterise the behaviour and vulnerabilities of such systems. The MANMADE project responds to this knowledge gap with its proposal to build advanced analysis tools. By applying complex systems analysis and related mathematical theories to these vital resources, as well as committed expertise, the project will offer better functions, improved methods and a safer place in which to live.

Manmade, and often interdependent, infrastructures are vital strategic assets. Their robust and affordable functioning is essential to Europe's socio-economic development and stability. But many of these systems are now being destabilised by radical change – the result of market deregulation, the unbundling of the energy and utilities sectors and the increasing dependence on imported resources. Importantly, the risk of disaster is further increased by the current threat of terrorist attacks.

However, while malicious actions are always possible, records indicate that major regional or nation-wide disruptions are often the result of chance events affecting systems operating at the limits of their capacities. The causes may be natural or of human origin, occurring over long and short time scales. Dangers include shifting supply-side geopolitics, natural processes and calamities (such as extreme weather, seismic activity and flooding) as well as the effects of climate change.

Technological factors such as ageing equipment, accidental damage and complex grid interconnections pose more threats and hazards, which often transcend the interests of individual Member States. For example, undamped frequency oscillations initiated at one point in an electricity grid can quickly propagate over thousands of kilometres, crossing national borders without restraint.

Long-term planning strategies for infrastructure development and risk containment are the subject of vigorous debate between utility owners, governments and the public at large. Yet, despite the magnitude of the problems, there remains a lack of knowledge and understanding of the macroscopic behaviour of Europe's essential networks.

Safeguarding vital systems

The aim of MANMADE is to assemble, develop and apply complementary mathematical methods for analysis of the so-called 'complex behaviour' of such large, manmade multi-

"Blend the blue-sky visions of scientists with the practical needs of the network professionals."

element infrastructures. This initiative focuses primarily on energy supply, emergency response systems and the key subsidiary structures that either depend directly on them or are relied upon in times of crisis.

While differing greatly, these systems share a need for qualitative and quantitative methods to provide insight into the processes that generate complex behaviour. The functioning of individual network components is well understood, but their interdependencies, key vulnerabilities and the consequences of a major disruption at some critical nodes remain unclear. Resolving these issues will assist not only in the development of civil emergency preparedness strategies but also in the general long-term planning of operating programmes and supply-chain relationships.

The MANMADE consortium assembled for this breakthrough project includes academic institutes from four EU Member States and one target country (Macedonia), whose role will be to provide expertise in pure and applied mathematics. They are joined by two stakeholder agencies – the National Emergency Supply Agency (Finland) and Gestore Mercato Elettrico (Italy) – which will direct the project towards real-world issues.

Although the project will make use of standard mathematical concepts of complex systems theory, new methods based on the spectral representation of weighted connectivity matrices will be introduced and tested on actual networks. MANMADE will also examine the role of feedback and scaling as the drivers for emergent phenomena, and to correlate volatility/persistence in coupled systems.

The MANMADE partners will map specific physical and service networks that make up the main elements of functional inter-connected networks. A prime motivating principle is that, although network owners and managing authorities may be aware of the underlying concepts of complex systems analysis, mathematicians have not yet fully proved its worth in this context.

Problem-solving, yet visionary

As well as conforming to the NEST philosophy of applying a practical problem-solving approach grounded on the observation of experimental data, the project strategy will also embrace direct liaison with industry and governments to develop specific case studies.

By fielding interdisciplinary teams, MANMADE will encourage the transfer of techniques for solving complexity problems from one area of science to another. It will blend the blue-sky visions of scientists with the practical needs of the network professionals. The project will bring together both the researchers and the technologists from the networked utilities, as well as the social entities responsible for maintaining and monitoring the systems being investigated.

The strong theoretical content of the proposed research will lead to a long-term educational endeavour. And, while driven by real application-oriented questions, it is possible that the new mathematical techniques developed will lead to applications beyond those envisaged within the project itself – potentially inspiring fresh ideas of immeasurable value.

AT A GLANCE

Official Title
Diagnosing Vulnerability, Emergent Phenomena, and Volatility in Manmade Networks

Coordinator
Queen Mary College London University (United Kingdom)

Partners
- JRC-IPSC (Italy)
- Collegium Budapest (Hungary)
- Macedonian Academy of Sciences and Arts (Macedonia)
- Universita Carlo Cattaneo LIUC (Italy)
- National Emergency Supply Agency (Finland)
- Gestore Mercato Elettrico (Italy)

Further Information
Prof David Arrowsmith
Queen Mary University of London
School of Mathematical Sciences
Mile End Road
E1 4NS London
United Kingdom
email: d.k.arrowsmith@qmul.ac.uk
fax: +44 208 981 9587

Project cost
€ 1 382 260

EU funding
€ 1 099 999

Project reference
Contract No 043363 (NEST)

Electricity supply and relay systems now depend on the interconnections of the pan-European network which makes them vulnerable and less stable.