MERC PhD Project Proposal

Title of the research project

Multi-risk analysis of supply chain networks

Keywords

Loss assessment, extreme events, natural hazard, hazard modelling, probabilistic assessment

Supervisors

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Project description

Driven by trade and investment liberalization and continued cost reduction pressures from customers, businesses have been extending worldwide to make the most of each location's comparative advantage. Many industries have adopted highly integrated global supply chains in which products are supplied, manufactured and distributed across national boundaries through offshore activities and outsourcing strategies. At the same time, economies of scale have driven the consolidation and agglomeration of firms in the supply chains, which have also promoted logistic consolidation. As a result, supply chains networks (SCNs) are becoming more complex with wider geographical coverage. SCNs are usually composed of five main elements: external suppliers, production centres, distribution centres, demand zones, and transportation assets. They can be modelled by direct graphs in which the nodes correspond to existing and potential supply sources, facilities and demand zones, and the arcs represent the transportation lanes that could be used to move materials (e.g., Klibi and Martel, 2012).
Along their business life, SCNs are periodically reengineered because strategic decisions are required to align the structure of the network to the needs of future business environments. The upgraded SCNs have to last for several years, thus alternative plausible futures must be considered to design robust value-creating networks. Recent events demonstrated that, in SCNs reengineering, not only ordinary business evolution scenarios but also (possible) disasters must be considered. Indeed, some well-known examples of disasters having huge impact on SCNs are the 9/11 terrorist attacks on the World Trade Centre in New York, the US blackout in 2004, the Katrina hurricane in 2005, the 2011 earthquakes in Chile and Japan and, in some sense, the still-ongoing CoVid-19 pandemic (e.g., Linghe and Masato, 2012, among others). Such examples underline the importance of considering the impact of extreme events in the SCNs reengineering. Unfortunately, current SCNs design models usually do not consider these events explicitly. Indeed, classical design procedures only consider business-as-usual random events which are modelled

referring to a set of plausible future scenarios with associated probabilities (e.g., Santos et al., 2005). This tends to produce networks with a small number of large facilities to benefit from economies of scale. However, this kind of networks are typically not very resilient because, when a facility is hit by a disaster event, there is no effective backup. On the other hand, when hazards are considered in the design process, the optimal networks organization should include more and smaller facilities to provide good backups.

Sheffi (2005) also stresses that modelling extreme events and their effects on SCNs is a challenging problem, due to the numerous types of possible catastrophes to consider, to the large territory over which the networks are deployed, and to their various impacts in time on network resources. Indeed, consequences of catastrophic events are not only related to the physical damages of the nodes and arches of the SCNs but also to other key design variables/parameters such as facility/supplier capacity and customer demand.

The challenge of this doctorate research program is to probabilistically account of all the events/variables that may be significant for SCNs. To this aim, the methodology currently adopted for engineering design of single structure, the so-called performance-based design (Cornell and Krawinkler, 2000), will be extended to design of SCNs. In this context, three types of threats can be distinguished (Chopra and Sodhi, 2004): (i) randomness, (ii) hazard and (iii) deep uncertainty. Randomness is characterized by random variables related to business-as-usual operations (e.g., customer demands, prices, and resource capacities). Hazard is representative of low probability unusual events with a high impact: this is the case of natural hazards such as earthquakes, tornado, tsunami, etc. Finally, deep uncertainty may be related to event characterized by the lack of any information to assess the probability of plausible future events such as terrorist attacks. The methodology to develop will aim to quantify the expected value of losses for a given configuration of a SCN in any period of interest and, comparing alternative configurations, to identify the optimal one, that is the one to which the lowest values of losses are associated.

Relevance to the MERC PhD Program

The research project is in strong accordance with the main objective of the MERC ph.d. program that aims at developing new methodological approaches to understand, model and engineer ever-growing reliable interdependent, complex and interconnected systems and infrastructures. The trained researcher will deal with a wide range of fields, studying methods usually adopted for risk assessment in earthquake engineering and applying such methods to complex systems and networks.

Application areas of developed skills include civil engineering, industrial product and process engineering, complex infrastructures and distribution networks, economics and finance.

The research results will be of interest for both productive firms and insurance and reassurance companies.

Key references

Chopra, S., Sodhi, M.S., (2004). Managing risk to avoid supply-chain breakdown. MIT Sloan Management Review 46, 52–61.

Cornell, C. A., and H. Krawinkler (2000). Progress and challenges in seismic performance assessment, PEER Cent. News, 3(2), 1–4

Klibi, W., and Martel, A. (2012). Scenarios-based supply chain networks risk modelling. European Journal of operational research, 223, 644-658.

Linghe, Y. and Masato, A. (2012). The impacts of natural disasters on global supply chains. ARTNeT Working Paper Series No. 115.

Santoso, T., Ahmed, S., Goetschalckx, M., Shapiro, A., (2005). A stochastic programming approach for supply chain network design under uncertainty. European Journal of Operational Research, 167, 96–115
Sheffi, Y., (2005). The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage. MIT Press

Joint supervision arrangements

Weekly meetings with the one or both supervisors will be scheduled during the whole research program.

Location and length of the study period abroad (min 12 months)

Any other useful information

The research will be developed together with the AXA XL company that is a leading group of the insurance market and with which the University of Naples have collaborated for several years.