
The Supernetwork Sentinel

The Newsletter of the Virtual Center for Supernetworks

Winter 2004



Welcome to the second edition of **The Supernetwork Sentinel**, the newsletter of the Virtual Center for Supernetworks at the Isenberg School of Management, UMass-Amherst. **The Supernetwork Sentinel** will be published in Fall, Winter, and Summer editions. Its purpose is to keep you informed of events, activities, and successes of the Virtual Center for Supernetworks. In this newsletter we include news items, noteworthy recognitions, an essay on critical infrastructure networks, and information regarding center activities.

Anna Nagurney
John F. Smith Memorial Professor
Director – Virtual Center for Supernetworks

Open House Held

On October 24, 2003 the Supernetworks Laboratory for Computation and Visualization was officially unveiled with an Open House. Guests from various departments and administrative offices at UMass along with visitors from outside the campus were hosted with tours, demos, slide shows, handouts, and a variety of pastries and treats. The warm and special event provided an excellent networking opportunity for students, faculty, administrators, and reps from industry. Professor Nagurney's new edited book, *Innovations in Financial and Economics Networks*, hot off the press from Edward Elgar Publishing was also featured there.



Dean O'Brien and Associate Dean Miller at the Open House

For more photos from the open house see the center's website:
<http://supernet.som.umass.edu>

Center and New Lab in the Media

Last term, the Center and its Associates and the New Supernetworks Lab were the subject of media attention. On November 23, 2003, we were featured on the Steve Lappas Show on the "Your State U." segment and were interviewed by Mr. Dominick Aielli. The segment, courtesy of Channel 40 and the UMass Athletic Department, can be viewed on the supernetworks site under "Videos." The students enjoyed the process, as did Professor Nagurney who also serves as the lab director.

Professor Nagurney was also interviewed by the press and interviews were published in the *Massachusetts Daily Collegian* and in *MassHighTech*.



The Supernetworks Center and its activities will be the cover subject in the next *Commonwealth* published by the Isenberg School of Management.

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Essay
Supernetworks: The Paradigm for Critical Infrastructure
and the
Supernetworked Economy
Anna Nagurney

In an invited essay in *OR/MS Today*, June 2000, entitled, "Navigating the Network Economy" <http://www.lionhrtpub.com/orms/orms-6-00/nagurney.html> I argued that we were in a new era of *Supernetworks*. Since that time the world has been transformed through events of historical proportions which have dramatically and vividly reinforced the dependence of our societies and economies on critical infrastructure networks including *physical* networks; i.e., transportation and logistical networks, communication networks, energy and power networks, as well as more *abstract* networks comprising: financial networks, environmental networks, social, and knowledge networks, and *combinations* thereof. Indeed, recent historical events have graphically illustrated the interconnectedness, interdependence, and vulnerability of organizations, businesses, and other enterprises on critical network infrastructure systems. The decisions made by the users of the networks, in turn, affect not only the users themselves but others, as well, in terms of safety and security, profits and costs, timeliness of deliveries, the quality of the environment, etc. Hence, the understanding of the impacts of human decision-making on such networks is of paramount importance.

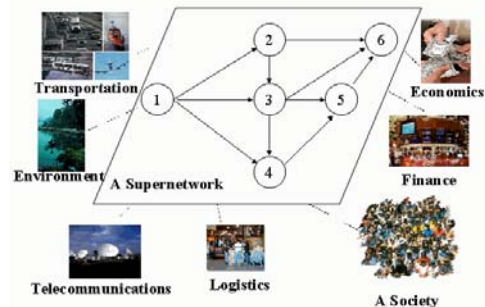
In this essay, I argue that Supernetworks are *the paradigm* for the modeling, analysis, and solution of critical infrastructure problems in the *Supernetworked Economy*. In particular, the supernetwork paradigm, as evidenced by the book *Supernetworks: Decision-Making for the Information Age*, by Nagurney and Dong (2002), along with many articles and applications (see: <http://supernet.som.umass.edu>), is sufficiently general and yet elegantly compact to formalize and make a major impact on the design, robustness, and evolution of critical infrastructure networks, their usage, evaluation, and management thereof. In particular, "Super" networks are networks that are "above and beyond" existing networks, which consist of nodes, links, and flows, with nodes corresponding to locations in space, links to connections in the form of roads, cables, etc., and flows to vehicles, data, etc. Supernetworks are conceptual in scope, graphical in perspective, and, with the accompanying theory, which is networked-based, predictive in nature.

The supernetwork framework, captures, in a unified fashion, decision-making facing a variety of decision-makers including consumers and

producers as well as distinct intermediaries, such as financial brokers, electric power transmitters, and electronic retailers in the context of today's supernetworked economy. The decision-making process may entail weighting trade-offs associated with the use of transportation versus telecommunication networks. The behavior of the individual decision-makers is modeled as well as their interactions on the complex network systems with the goal of identifying the resulting flows and prices. By being able to predict the various flows based on network topologies and interactions amongst the decision-makers one then gains deep insights into the vulnerabilities as well as the strengths of various linkages.

The origins of supernetworks can be traced to the study of transportation networks, telecommunication networks, as well as economic and financial networks, and, interestingly, to biology, as reviewed in Nagurney and Dong (2002). Here I take that synthetic and rigorous approach. In the Figure below, I provide a conceptualization of supernetworks for critical infrastructure that emphasizes the interdependence of distinct network systems. Note that the image dates to 2001 which coincides with the establishment of the Virtual Center for Supernetworks.

Clearly, one of the principal facets of critical



infrastructure networks is the interaction among the networks themselves. For example, the increasing use of electronic commerce especially in business to business transactions is changing not only the utilization and structure of the underlying logistical networks but is also revolutionizing how business itself is transacted and the structure of firms and industries. Cellular phones are being used as vehicles move

dynamically over transportation networks resulting in dynamic evolutions of the topologies themselves. Power outages in one part of the world may affect transportation and financial systems around the globe as the August 14, 2003 blackout demonstrated. The unifying concept of supernetworks with associated methodologies allows one to explore the interactions among such networks as transportation networks, telecommunication networks, as well as financial networks, to capture the dynamic interactions and also to measure the associated risks and gains/losses.

Supernetworks and Applications

Supernetworks may be comprised of such networks as transportation, telecommunication, logistical and financial networks, among others. They may be *multilevel* as when they formalize the study of supply chain networks or *multitiered* as in the case of financial networks with intermediation. Furthermore, decision-makers on supernetworks may be faced with multiple criteria and, hence, the study of supernetworks also includes the study of multicriteria decision-making. In the Table below, some specific applications of supernetworks are given, which have been studied by myself with students and colleagues. Subsequently, I elaborate upon several of the applications. For various publications on these topics, see: <http://supernet.som.umass.edu>

Examples of Supernetwork Critical Infrastructure Applications
Telecommuting/Commuting Decision-Making
Teleshopping/Shopping Decision-Making
Supply Chain Networks with Electronic Commerce
Financial Networks with Electronic Transactions
Environmental and Energy Networks including E-Cycling Networks
Knowledge and Social Networks

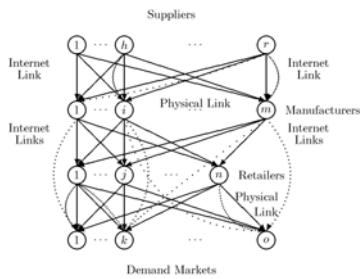
In particular, the supernetwork framework allows one to formalize the alternatives available to decision-makers, to model their individual behavior, typically, characterized by particular criteria which they wish to optimize, and to, ultimately, compute the flows on the supernetwork, which may consist of product shipments, travelers between origins and destinations, financial flows, energy flows, as well as the associated "prices." Hence, the concern is with *human decision-making* and how the supernetwork concept can be utilized to crystallize and inform in this dimension.

Supply Chain Networks and Electronic Commerce

The study of supply chain network problems through modeling, analysis, and computation is a challenging topic due to the complexity of the relationships among the various decision-makers, such as suppliers, manufacturers, distributors, and retailers as well as the practical importance of the topic for the efficient movement of products. The topic is multidisciplinary by nature since it involves particulars of manufacturing, transportation and logistics, retailing/marketing, as well as economics. In today's world, there is growing uncertainty and risk due to various threats and even illnesses such as SARS which have affected dramatically the timely delivery of goods and have impacted transportation of humans as well.

The introduction of electronic commerce has, however, unveiled new opportunities in terms of research and practice in supply chain analysis and management since electronic commerce (e-commerce) has had a huge effect on the manner in which businesses order goods and have them transported with the major portion of e-commerce transactions being in the form of business-to-business (B2B). Estimates of B2B electronic commerce range from approximately .1 trillion dollars to 1 trillion dollars in 1998 and with forecasts reaching as high as \$4.8 trillion dollars in 2003 in the United States. It has been emphasized that the principal effect of business-to-business (B2B) commerce, estimated to be 90% of all e-commerce by value and volume, is in the creation of new and more profitable supply chain networks.

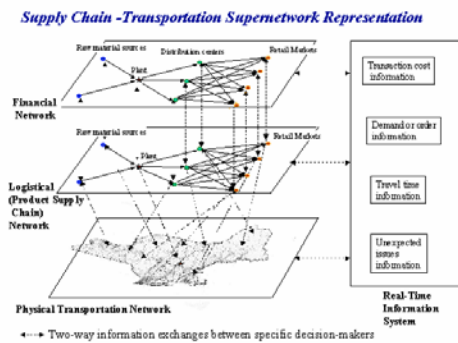
In the next Figure, I depict a four-tiered supply chain network in which the top tier consists of suppliers of inputs into the production processes used by the manufacturing firms (the second tier), who, in turn, transform the inputs into products which are then shipped to the third tier of decision-makers, the retailers, from whom the consumers can then obtain the products. Here we allow not only for physical transactions to take place but also for virtual transactions, in the form of electronic transactions via the Internet to represent electronic commerce. In the supernetwork framework, both B2B and B2C can be considered, modeled, and analyzed. The decision-makers may compete independently across a given tier of nodes of the network and cooperate between tiers of nodes.



In particular, Nagurney, Loo, Dong, and Zhang (2002) in *Netnomics* have applied the supernetwork framework to supply chain networks with electronic commerce in order to predict product flows between tiers of decision-makers as well as the prices associated with the different tiers. They assumed that the manufacturers as well as the retailers are engaged in profit-maximizing behavior whereas the consumers seek to minimize the costs associated with their purchases. The model therein determines the volumes of the products transacted electronically or physically.

As mentioned earlier, supernetworks may also be multilevel in structure. In particular, Nagurney, Ke, Cruz, Hancock, and Southworth (2002) in *Environment and Planning B* demonstrated how supply chain networks can be depicted and studied as multilevel networks in order to identify not only the product shipments but also the financial flows as well as the informational ones.

Below, I recall how a supply chain can be depicted as a multilevel supernetwork in which the financial network as well as the actual physical transportation network are also represented.



For example, in the supernetwork just depicted, the logistical network affects the flows on the actual transportation network whereas the financial flows are due to payments as they proceed up the chain and as the transactions are completed. The information flows, in turn, are in the form of demand, cost, and flow data at the instance in time.

Obviously, in the setting of supply chain networks and, in particular, in global supply chains, there may be much risk and uncertainty associated with the underlying functions. Some research along these lines has already yielded promising results (cf. Nagurney, Cruz, Dong, and Zhang (2003) *European Journal of Operational Research*, in press). Continuing efforts to include uncertainty and risk into modeling and computational efforts in a variety of supernetworks and their applications is of paramount importance given the present economic and political climate.

In addition, I emphasize that the inclusion of environmental variables and criteria is also an important topic for research and practice in the context of supply chain networks as has been demonstrated recently by Nagurney and Fuminori (2003) in *Transportation Research D* and is being presently investigated by my group in the context of electric power networks.

Financial Networks and Electronic Transactions

Financial networks have been utilized in the study of financial systems since the work of Quesnay in 1758, who depicted the circular flow of funds in an economy as a network. His conceptualization of the funds as a network, which was abstract, is the first identifiable instance of a supernetwork.

Quesnay's basic idea was subsequently applied in the construction of flow of funds accounts, which are a statistical description of the flows of money and credit in an economy (cf. Board of Governors (1980)). However, since the flow of funds accounts are in matrix form, and, hence, two-dimensional, they fail to capture the behavior on a micro level of the various financial agents/sectors in an economy, such as banks, households, insurance companies, etc. Moreover, the generality of the matrix tends to obscure certain structural aspects of the financial system that are of continuing interest in analysis, with the structural concepts of concern including those of financial intermediation.

Advances in telecommunications and, in particular, the adoption of the Internet by businesses, consumers, and financial institutions have had an enormous effect on financial services and the options available for financial transactions. Distribution channels have been transformed, new types of services and products introduced, and the role of financial intermediaries altered in the new supernetworked landscape. Furthermore, the impact of such advances has not been limited to individual nations but, rather, through new linkages, has crossed national boundaries.

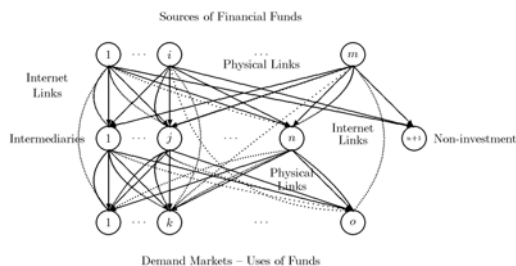
The topic of *electronic* finance has been a growing area of study as described in Nagurney's 2003 edited volume, *Innovations in Financial and Economic Networks*, due to its increasing impact on financial markets and financial intermediation, and the related regulatory issues and governance. Of particular emphasis has been the conceptualization of the major issues involved and the role of networks is the transformations.

The complexity of the interactions among the distinct decision-makers involved, the supply chain aspects of the financial product accessibilities and deliveries, as well as the availability of physical as well as electronic options, and the role of intermediaries, have recently been addressed in unified, quantifiable framework which one can assess the resulting financial flows and prices in a series of papers by Nagurney and Ke and Nagurney and Cruz.

Here, I briefly describe a supernetwork framework for the study of financial decision-making in the presence of intermediation and electronic transactions. Further details can be found in Nagurney and Ke (2001, 2003) in the journal *Quantitative Finance* and Nagurney and Cruz (2003) in *Innovations in Financial and Economic Networks*. The framework is sufficiently general to allow for the modeling, analysis, and computation of solutions to such problems.

The financial network model consists of: agents or decision-makers with sources of funds, financial intermediaries, as well as consumers associated with the demand markets. In the model, the sources of funds can transact directly electronically with the consumers through the Internet and can also conduct their financial transactions with the intermediaries either physically or electronically. The intermediaries, in turn, can transact with the consumers either physically in the standard manner or electronically.

The depiction of the network at equilibrium is given in the Figure below.



It is assumed that the agents with sources of funds as well as the financial intermediaries seek to maximize their net revenue (in the presence of transaction costs) while, at the same time, minimizing the risk associated with the financial products. The solution of the model yields the

financial flows between the tiers as well as the prices. We also allow for the option of having the source agents not invest a part (or all) of their financial holdings.

More recently, Nagurney and Cruz in a forthcoming *Computational Management Science* article have demonstrated that the financial supernetwork framework can also be extended to model international financial networks with intermediation in which there are distinct agents in different countries and the financial products are available in different currencies.

In this essay, I have argued for the Supernetwork paradigm as a powerful tool for the study of critical infrastructure networks, emphasizing that it can capture not only the interrelationships among networks but, most importantly, the effects of human decision-making on the induced flows and prices. Through the computation of the flows and prices one can determine the true network designs as well as the associated vulnerabilities. Hence, supernetworks provide not only powerful engineering and operations research /management science tools to bear but also financial and economic ones. Finally, the supernetwork paradigm uniquely captures the human aspects and brings a richness to conceptualization and understanding of the underlying processes.

References are available at <http://supernet.som.umass.edu> under "Publications/Downloadable Articles."

Kudos and Congratulations

Congratulations to Professor David E. Boyce on his receipt of the Robert Herman Lifetime Achievement Award in Transportation Science from the Transportation and Logistics Section at the INFORMS National Meeting held in Atlanta, GA, October 19-22, 2003. At the same meeting, David Boyce was elected one of thirteen new INFORMS Fellows. Photos of the ceremonies can be found at: <http://supernet.som.umass.edu>



Professor Boyce with his INFORMS Fellow Plaque

Wrapups

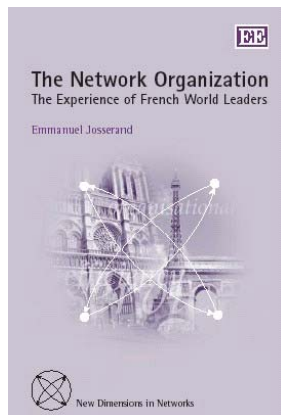
In the Fall 2003 newsletter, we highlighted the panel on the Retrospective of the Beckmann, McGuire, and Winsten (1956) book *Studies in the Economics of Transportation* organized by Professor David E. Boyce for the **50th Regional Science Association Meeting** in Philadelphia, PA. The panel took place on November 22, 2003 to a packed audience. The presentations of the panelists: Professors David E. Boyce, Hani Mahmassani, and Anna Nagurney can be found on the supernetworks site. Professor Suzanne Evans from Birbeck College, UK, served as the discussant. The panelists have prepared an invited article on the impacts of the book for *OR/MS Today*, an INFORMS publication.



Professors Mahmassani, Evans, Boyce, and Anna Nagurney

New Books

We are pleased to announce that the third volume in the New Dimensions in Networks series that Professor Nagurney edits for Edward Elgar Publishing entitled **Urban and Regional Transportation Modeling: Essays in Honor of David E. Boyce**, edited by Der-Horng Lee, will be available in the Spring 2004. The fourth volume in the series scheduled for shortly thereafter is **The Network Organization: The Experience of French World Leaders**, authored by Emmanuel Jossierand. More information on these new books can be found on the supernetworks center site.



Center Associate News

Welcome to **Li Zhao**, who is originally from China and has enrolled in the doctoral program at the Isenberg School of Management at UMass-Amherst with a concentration in Management Science. Li is not new to UMass since he received an MS in Resource Economics in 2003. Li has already assumed an active role in the center and lab activities given his expertise in econometrics and his energy and enthusiasm. He is also an expert in Chinese calligraphy.

The Center also welcomes its second undergraduate student associate of the 2003-2004 academic year, **Gregory Bergmann**, who is an Operations Management major at the Isenberg School of Management. Mr. Bergmann completed Professor Nagurney's Management Science course and her Transportation & Logistics course.

Two of the center's doctoral student associates, Jose Cruz and Ke Ke, expect to defend their doctoral dissertations this term. Jose's thesis title is: *International Financial Networks and Global Supply Chains: A Unified Framework for Decision-Making, Optimization, and Risk Management*. Ke's title is: *Statics and Dynamics of Complex Network Systems: Supply Chain Analysis and Financial Networks with Intermediation*. Professor Nagurney is serving as the chair of their dissertations.

Ke Ke will also be teaching the undergraduate Management Science course this term. Jose Cruz, along with center doctoral associates Dmytro Matsypura and Fuminori Toyasaki, will be team-teaching an undergraduate Advanced Topics in Management Science course. This trio was supported, in part, by two of Professor Nagurney's Industrial Ecology Fellowships from the AT&T Foundation. A project of the students in the class, upon the request of the UMass Chief of Police, Ms. Barbara O'Connor, and with Professor Nagurney's approval, will be to undertake a study of how to improve the traffic flow for the 2004 UMass Commencement.

Congratulations to Tina Wakolbinger, a doctoral student associate, who will be giving a workshop with Professor Nagurney entitled, **Supernetworks for the Management of Knowledge Intensive Dynamic Systems**, at the Fourth International Conference on Knowledge, Culture and Organisations, to be held at the University of Greenwich, London, August 4-6, 2004.

Upcoming Events

2004 promises to be a very busy and eventful year for the Supernetworks Center.

In mid January, Professor Nagurney, along with Jose Cruz, will be traveling to New Hampshire to deliver a talk to APICS members on Supernetworks: Decision-Making in the 21st Century. Professor Nagurney will also be traveling to the National Science Foundation to present a paper with Dmytro Matsypura at the STELLA Workshop.

Professor Nagurney will be giving several invited talks at various universities in the US this term and will also be spending several weeks in March at the Rockefeller Foundation's Bellagio Center on Lake Como. There she will be conducting research on global supply chain networks and international financial networks along with Professors Monica Cojocaru and Patrizia Daniele.

Professor Nagurney is organizing several sessions for the CORS/INFORMS International Meeting to be held in Banff, Alberta, Canada, May 16-19, 2004. She is also on the program committee of the 2004 Computing in Economics and Finance Conference to be held in Amsterdam, The Netherlands, July 8-10, 2004.

Professor Nagurney will be an invited speaker at the Economic Aspects of Congested Networks and Queues Conference to be held in Bonn, Germany, July 9-11, 2004.

Center Publications

Copies of center articles may be obtained at <http://supernet.som.umass.edu/dart.html>

Book: *Innovations in Financial and Economic Networks*, Anna Nagurney, editor, Edward Elgar Publishing, Cheltenham, England, 2003.

A Space-Time Network for Telecommuting versus Commuting Decision-Making, Anna Nagurney, June Dong, and Patricia L. Mokhtarian, *Papers in Regional Science* **82**: (2003), pp. 451-473

Reverse Supply Chain Management and Electronic Waste Recycling: A Multitiered Network Equilibrium Framework for E-Cycling, Anna Nagurney and Fuminori Toyasaki, to appear in *Transportation Research E: Transportation and Logistics*

Supply Chain Networks, Electronic Commerce, and Supply Side and Demand Side Risk, Anna Nagurney, Jose Cruz, June Dong, and Ding Zhang, to appear in *European Journal of Operational Research*

A Supply Chain Network Economy: Modeling and Qualitative Analysis, Ding Zhang, June Dong, and Anna Nagurney, in *Innovations in Financial and Economic Networks*, Anna Nagurney, editor, Edward Elgar Publishing, Cheltenham, England (2003), pp. 197-213

Multitiered Supply Chain Networks: Multicriteria Decision-Making under Uncertainty, June Dong, Ding Zhang, Hong Yan, and Anna Nagurney, revised and resubmitted to *Annals of Operations Research*

International Financial Networks with Electronic Transactions, Anna Nagurney and Jose Cruz, in *Innovations in Financial and Economic Networks*, Anna Nagurney, editor, Edward Elgar Publishing, Cheltenham, England (2003), pp. 136-168

Supernetworks: Paradoxes, Challenges, and New Opportunities, Anna Nagurney in *Transforming Enterprise*, W. Dutton, B. Kahin, R. O'Callaghan, and A. Wyckoff, editors, MIT Press, Cambridge, MA (2004), in press

International Financial Networks with Intermediation: Modeling, Analysis, and Computations, Anna Nagurney and Jose Cruz, to appear in *Computational Management Science* **1**

Spatial Equilibration in Transport Networks, Anna Nagurney, in *Handbook of Transport Geography and Spatial Systems*, P. Stopher, K. J. Button, K. Haynes, and D. A. Hensher, editors, Elsevier, The Netherlands (2004), in press.

Management of Knowledge Intensive Systems as Supernetworks: Modeling, Analysis, Computations, and Applications, Anna Nagurney and June Dong

Global Supply Chain Networks and Risk Management, Anna Nagurney, Jose Cruz, and June Dong

Dynamics of International Financial Networks with Risk Management, Anna Nagurney and Jose Cruz

Statics and Dynamics of Global Supply Chain Networks with Environmental Decision-Making, Anna Nagurney, Jose Cruz, and Fuminori Toyasaki

Dynamics of Global Supply Chain Supernetworks in a New Era of Risk and Uncertainty, Anna Nagurney and Dmytro Matsypura

Thanks and Acknowledgments

The Center Director and Associates would like to extend their sincerest appreciation and thanks to all those who attended our Open House on October 24, 2003.

The Center Director and Associates thank also Mr. Pat Callahan of the UMass News Office and Mr. Lou Wigdor, Communications Director of the Isenberg School, for their news releases regarding the center and its various activities. Special thanks go to Mr. Bill Strickland, the Associate Athletic Director at UMass for his support in having the Supernetworks Team featured in the Steve Lappas Show.

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