# Globally Networked Risks and How to Respond

**Today's strongly connected, global networks have produced highly interdependent systems that we do not understand and cannot control well. These systems are vulnerable to failure at all scales, posing serious threats to society, even when external shocks are absent. As the complexity and interaction strengths in our networked world increase, man-made systems can become unstable, creating uncontrollable situations even when decision-makers are well-skilled, have all data and technology at their disposal, and do their best. To make these systems manageable, a fundamental redesign is needed. A 'Global Systems Science' might create the required knowledge and paradigm shift in thinking.**

*Living in a Hyper-Connected World*

Our global networks have generated many benefits and new opportunities. However, they have also established highways for failure propagation, which can ultimately result in man-made disasters. For example, today's quick spreading of emerging epidemics is largely a result of global air traffic, with serious impacts on global health, social welfare, and economic systems.

Helbing's publication illustrates how cascade effects and complex dynamics amplify the vulnerability of networked systems. For example, just a few long-distance connections can largely decrease our ability to mitigate the threats posed by global pandemics. Initially beneficial trends, such as globalization, increasing network densities, higher complexity, and an acceleration of institutional decision processes may ultimately push man-made or human-influenced systems towards systemic instability, Helbing finds. Systemic instability refers to a system, which will get out of control sooner or later, even if everybody involved is well skilled, highly motivated and behaving properly. Crowd disasters are shocking examples illustrating that many deaths may occur even when everybody tries hard not to hurt anyone.

*Our Intuition of Systemic Risks Is Misleading*

Networking system components that are well-behaved in separation may create counter-intuitive emergent system behaviors, which are not well-behaved at all. For example, cooperative behavior might unexpectedly break down as the connectivity of interaction partners grows. "Applying this to the global network of banks, this might actually have caused the financial meltdown in 2008," believes Helbing.

Globally networked risks are difficult to identify, map and understand, since there are often no evident, unique cause-effect relationships. Failure rates may change depending on the random path taken by the system, with the consequence of increasings risks as cascade failures progress, thereby decreasing the capacity of the system to recover. "In certain cases, cascade effects might reach any size, and the damage might be practically unbounded," says Helbing. "This is quite disturbing and hard to imagine." All of these features make strongly coupled, complex systems difficult to predict and control, such that our attempts to manage them go astray.

"Take the financial system," says Helbing. "The financial crisis hit regulators by surprise." But back in 2003, the legendary investor Warren Buffet warned of mega-catastrophic risks created by large-scale investments into financial derivatives. It took 5 years until the "investment time bomb" exploded, causing losses of trillions of dollars to our economy. "The financial architecture is not properly designed," concludes Helbing. "The system lacks breaking points, as we have them in our electrical system." This allows local problems to spread globally, thereby reaching catastrophic dimensions.

*A Global Ticking Time Bomb?*

Have we unintentionally created a global time bomb? If so, what kinds of global catastrophic scenarios might humans face in complex societies? A collapse of the world economy or of our information and communication systems? Global pandemics? Unsustainable growth or environmental change? A global food or energy crisis? A cultural clash or global-scale conflict? Or will we face a combination of these contagious phenomena – a scenario that the World Economic Forum calls the "perfect storm"?

"While analyzing such global risks," says Helbing, "one must bear in mind that the propagation speed of destructive cascade effects might be slow, but nevertheless hard to stop. It is time to recognize that crowd disasters, conflicts, revolutions, wars, and financial crises are the undesired result of operating socio-economic systems in the wrong parameter range, where systems are unstable." In the past, these social problems seemed to be puzzling, unrelated, and almost "God-given" phenomena one had to live with. Nowadays, thanks to new complexity science models and large-scale data sets ("Big Data"), one can analyze and understand the underlying mechanisms, which let complex systems get out of control.

Disasters should not be considered "bad luck". They are a result of inappropriate interactions and institutional settings, caused by humans. Even worse, they are often the consequence of a flawed understanding of counter-intuitive system behaviors. "For example, it is surprising that we didn't have sufficient precautions against a financial crisis and well-elaborated contingency plans," states Helbing. "Perhaps, this is because there should not be any bubbles and crashes according to the predominant theoretical paradigm of efficient markets." Conventional thinking can cause fateful decisions and the repetition of previous mistakes. "In other words: While we want to do the right thing, we often do wrong things," concludes Helbing. This obviously calls for a paradigm shift in our thinking. "For example, we may sanction deviations from social norms to promote social order, but may trigger conflict instead. Or we may increase security measures, but get more terrorism. Or we may try to promote innovation, but suffer economic decline, because innovation requires diversity more than homogenization."

*Global Networks Must Be Re-Designed*

Helbing's publication explores why today's risk analysis falls short. "Predictability and controllability are design issues," stresses Helbing. "And uncertainty, which means the impossibility to determine the likelihood and expected size of damage, is often man-made." Many systems could be better managed with real-time data. These would allow one to avoid delayed response and to enhance the transparency, understanding, and adaptive control of systems. However, even all the data in the world cannot compensate for ill-designed systems such as the current financial system. Such systems will sooner or later get out of control, causing catastrophic man-made failure. Therefore, a re-design of such systems is urgently needed.

Helbing's Nature paper on "Globally Networked Risks" also calls attention to strategies that make systems more resilient, i.e. able to recover from shocks. For example, setting up backup systems (e.g. a parallel financial system), limiting the system size and connectivity, building in breaking points to stop cascade effects, or reducing complexity may be used to improve resilience. In the case of financial systems, there is still much work to be done to fully incorporate these principles.

Contemporary information and communication technologies (ICT) are also far from being failure-proof. They are based on principles that are 30 or more years old and not designed for today's use. The explosion of cyber risks is a logical consequence. This includes threats to individuals (such as privacy intrusion, identity theft, or manipulation through personalized information), to companies (such as cybercrime), and to societies (such as cyberwar or totalitarian control). To counter this, Helbing recommends an entirely new ICT architecture inspired by principles of decentralized self-organization as observed in immune systems, ecology, and social systems.

*Coming Era of Social Innovation*

Socio-inspired technologies built on decentralized mechanisms that create reputation, trust, norms or culture will be able to generate enormous value. "Facebook, based on the simple principle of social networking, is worth more than 50 billion dollars," Helbing reminds us. "ICT systems are now becoming artificial social systems. Computers already perform the great majority of financial transactions, which humans carried out in the past." But if we do not understand socially interactive systems well, coordination failures, breakdowns of cooperation, conflict, cyber-crime or cyber-war may result.

Therefore, a better understanding of the success principles of societies is urgently needed. "For example, when systems become too complex, they cannot be effectively managed top-down" explains Helbing. "Guided self-organization is a promising alternative to manage complex dynamical systems bottom-up, in a decentralized way." The underlying idea is to exploit, rather than fight, the inherent tendency of complex systems to self-organize and thereby create a robust, ordered state. For this, it is important to have the right kinds of interactions, adaptive feedback mechanisms, and institutional settings, i.e. to establish proper "rules of the game". The paper offers the example of an intriguing "self-control" principle, where traffic lights are controlled bottom-up by the vehicle flows rather than top-down by a traffic center.

*Creating and Protecting Social Capital*

It is important to recognize that many 21st century challenges such as the response to global warming, energy and food problems have a social component and cannot be solved by technology alone. The key to generating solutions is a Global Systems Science (GSS) that brings together crucial knowledge from the natural, engineering and social sciences. The goal of this new science is to gain an understanding of global systems and to make "systems science" relevant to global problems. In particular, this will require the combination of the Earth Systems Sciences with the study of behavioral aspects and social factors.

"One man's disaster is another man's opportunity. Therefore, many problems can only be successfully addressed with transparency, accountability, awareness, and collective responsibility," underlines Helbing. "For example, social capital is important for economic value generation, social well-being and societal resilience, but it may be damaged or exploited, like our environment," explains Helbing. "Humans must learn how to quantify and protect social capital. A warning example is the loss of trillions of dollars in the stock markets during the financial crisis." This crisis was largely caused by a loss of trust.

"It is important to stress that risk insurances today do not consider damage to social capital," Helbing continues. However, it is known that large-scale disasters have a disproportionate public impact, in part because they destroy social capital. As we neglect social capital in risk assessments, we are taking excessive risks.

*New Instruments for the 21$^{st}$ Century*

Finally, to gain the urgently needed insights, the study suggests to build new instruments, as proposed by the FuturICT initiative (http://www.futurict.eu): This comprises a "Planetary Nervous Systems" (PNS) to measure the state of our planet in real-time, capturing also socio-economic trends, social capital, and the "social footprint" of human decisions and actions. These data may be fed into a "Living Earth Simulator" (LES) to study "what … if" scenarios. A "policy wind tunnel" or "socio-economic flight simulator" of this kind could provide better, evidence-based advice for decision makers, be it politicians, business leaders, or citizens. It could help us to identify opportunities and alert us of risks or unwanted side effects. Last but not least, the "Global Participatory Platform" (GPP) would open up the above-mentioned tools for everyone and support collaboration, interactive exploration, and crowd sourcing.

This bold vision can be realized, provided that we learn how to design and operate open, value-oriented ICT systems and how to promote a non-malicious and self-determined use of data. It would take a major investment: an Apollo-like project focusing on techno-socio-economic-environmental systems, life on earth and everything it relates to. Helbing is convinced: "it would be the best investment humanity can make".

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Webpages: http://www.soms.ethz.ch, http://www.futurict.eu

See also
- "Denial of catastrophic risks", http://www.sciencemag.org/content/339/6124/1123.full
- World Economic Forum, *Global Risks 2011*, *2012*, and *2013* (WEF, Geneva, Switzerland, 2011, 2012, 2013), downloadable via http://www.weforum.org/issues/global-risks.

Supplementary Videos:

- http://vimeo.com/53876434 Spreading and erosion of cooperation in a social dilemma situation
- http://vimeo.com/53872893 Cascade spreading is increasingly hard to recover from as failure progresses. The simulation model mimics spatial epidemic spreading with air traffic and healing costs.

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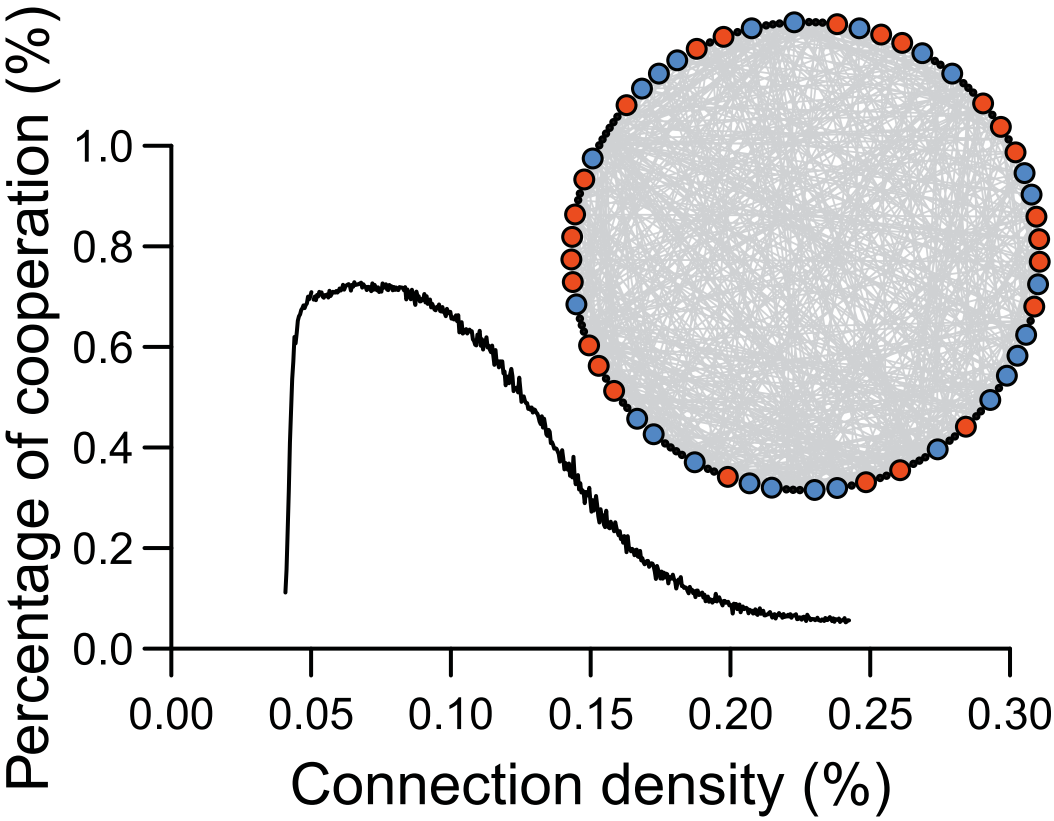
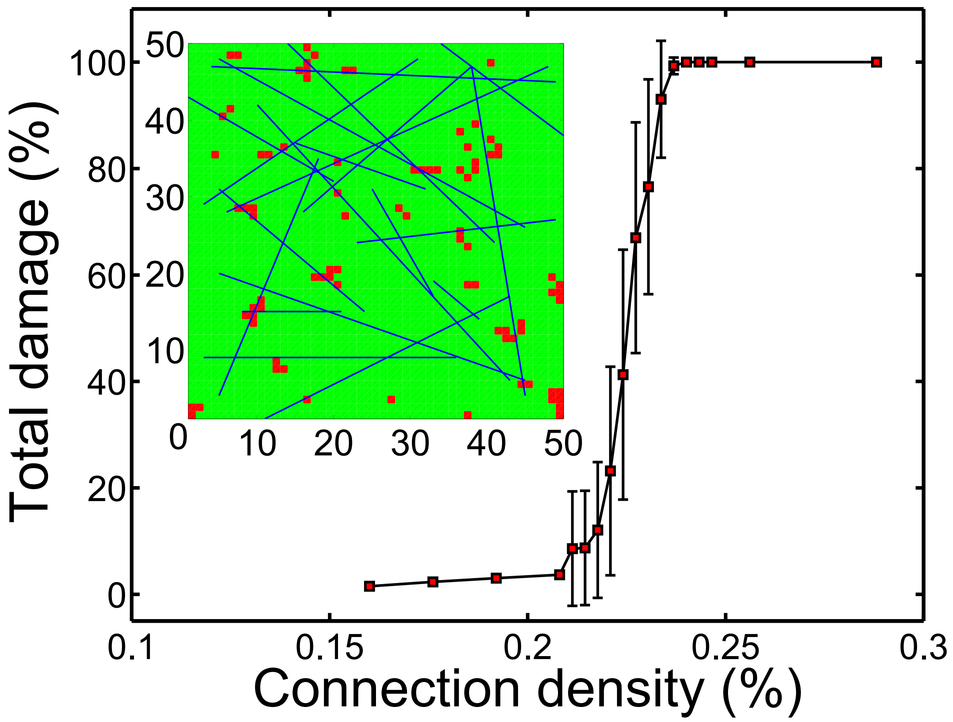



**Spreading and erosion of cooperation in a prisoner's dilemma game.** The computer simulations assume the payoff parameters $T = 7$, $R = 6$, $P = 2$, and $S = 1$ and include success-driven migration. Although cooperation would be profitable to everyone, non-cooperators can achieve a higher payoff than cooperators, which may destabilize cooperation. The graph shows the fraction of cooperative agents, averaged over 100 simulations, as a function of the connection density (actual number of network links divided by the maximum number of links when all nodes are connected to all others). Initially, an increasing link density enhances cooperation, but as it passes a certain threshold, cooperation erodes. (See http://vimeo.com/53876434 for a related movie.) The computer simulations are based on a circular network with 100 nodes, each connected with the four nearest neighbours. $n$ links are added randomly. 50 nodes are occupied by agents. Blue circles represent cooperation, red circles non-cooperative behaviour, and black dots empty sites. Initially, all agents are non-cooperative. Their network locations and behaviours (cooperation or defection) are updated in a random sequential way in 4 steps: (1) The agent plays two-person prisoner's dilemma games with its direct neighbours in the network. (2) After the interaction, the agent moves with probability 0.5 up to 4 steps along existing links to the empty node that gives the highest payoff in a fictitious play step, assuming that noone changes the behaviour. (3) The agent imitates the behaviour of the neighbour who got the highest payoff in step 1 (if higher than the own one). (4) The behaviour is spontaneously changed with a mutation rate of 0.1.




**Cascade spreading is increasingly hard to recover from as failure progresses.** The simulation model mimics spatial epidemic spreading with air traffic and healing costs in a two-dimensional 50 × 50 grid with periodic boundary conditions and random shortcut links. The colourful inset depicts an early snapshot of the simulation with $N = 2500$ nodes. Red nodes are infected, green nodes are healthy. Shortcut links are shown in blue. The connectivity-dependent graph shows the mean value and standard deviation of the fraction $i(t)/N$ of infected nodes over 50 simulation runs. Most nodes have four direct neighbours, while a few of them possess an additional directed random connection to a distant node. The spontaneous infection rate is $s = 0.001$ per time step; the infection rate by an infected neighbouring node is $P = 0.08$. Newly infected nodes may infect others or may recover from the next time step onwards. Recovery occurs with a rate $q = 0.4$, if there is enough budget $b > c$ to bear the healing costs $c = 80$. The budget needed for recovery is created by the number of healthy nodes $h(t)$. Hence, if $r(t)$ nodes are recovering at time $t$, the budget changes according to $b(t + 1) = b(t) + h(t) - cr(t)$. As soon as the budget is used up, the infection spreads explosively. (See also the movie at http://vimeo.com/53872893.)