# Collaborative Sciences Center for Road Safety – Coffee and Conversation Speaker Series

## PROCEEDINGS from “An Introduction to Systems Thinking”

## Richard Burgess

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In *An Introduction to Systems Thinking*, Richard Burgess applies principles of systems thinking to the problems of ethics faced by engineers. Burgess recognizes that engineers face trade-offs and decisions in their daily work that can dramatically impact the systems in which we operate. In this talk for CSCRS Coffee & Conversations, Burgess outlined the basic principles of systems thinking, the connection between ethics and systems, how professionals can apply it to our work, and how systems that we design can be Aristotelian and conducive to ‘practical wisdom.’

Burgess’s doctoral work in systems engineering focuses on how to get engineers to think ethically. He is currently at the Murdough Center & National Institute for Engineering Ethics at Texas Tech University, and applies his undergraduate and Masters degrees in philosophy to his current work.

Understanding the basic principles of systems thinking requires first defining what is a system. Systems are not simply ‘looking at the big picture,’ and as research and practice become increasingly inter-disciplinary it is more critical than ever to understand whether we are operating in a system. Anderson and Johnson [1] formalize a few key characteristics of systems:

1. A system is composed of parts that must all be present for the system to carry optimal function.
2. Must be arranged in a specific way for the system to carry out its purpose – in other words, the order counts.
3. Systems have specific purposes within larger systems.
4. Systems maintain their stability through fluctuations and adjustments – in other words, they can maintain harmony through inflows and outflows.
5. Systems have feedback.

Examples of systems appear in every discipline, including architecture, healthcare, manufacturing, ecology, and transportation.

Bertalanffy developed his General System Theory [2] partly as a reaction to reductionism in 20th century thinking, which posited that humans could understand the environment only by drilling down to an increasingly smaller level of detail. This kind of thinking discarded consideration of interaction effects and how pieces work together at a macro level. General System Theory’s key concepts include:

* Equifinality: the same state can be reached by multiple paths. For example, in a transportation system some people walk, some drive, some take transit, and some bike.
* Negative entropy: systems move toward greater complexity. We see examples of this in the world as international relations and technology increasingly complicate interactions and activities.
* Steady state vs. equilibrium (and static vs. dynamic equilibrium): equilibrium is a characteristic of closed systems, while open systems can reach a steady state. The time horizon and the scope are important in determining if a system is open or closed.
* Emergent properties: the whole is greater than the sum of its parts.

Isomorphology is another systems concept that occurs when two or more systems demonstrate key structural similarities. These similarities can occur at multiple levels from analogy to explanation and can help us understand system processes and behaviors.

What is the connection between systems thinking and philosophy? Systems thinking has implications for how we understand the world, what values or meanings we assign, and how we normalize certain behaviors or processes. Philosophy can help us understand how we approach systems and optimize them for certain outcomes. Combining the two can potentially help engineers or other professionals to better recognize when they are in a system and how the system is creating or contributing to desirable or undesirable outcomes.

Burgess’s proposal for ethics in system engineering is an Aristotelian system. Aristotle’s Nichomachean Ethics [3] posits that “eudaimonia” is a happiness or flourishing common to all human beings, and that humans have intellectual and moral virtues. One major contribution of Nichomachen Ethics is the concept of ‘practical wisdom,’ which argues that it is not enough to have good thoughts or intentions—such intentions should be acted upon.

Aristotelian Systems have specific goals:

1. The system should not interfere with happiness—i.e., eudaimonia—but instead should promote it.
2. The system should be conducive to the practice of virtue for both the system designer and the user.

In practice, engineers and other system designers can use these goals to think more ethically about their systems. For example, since happiness is central and common for us as human beings, designers of a transportation system might model or test a system beforehand to make sure that it does not reduce or impede happiness. In some ways, traffic engineers already do this. They focus on maximizing safety—e.g., injury and death are run counter to happiness. However, these same engineers may also fail to account for design elements or processes that reduce happiness overall or reduce happiness for some users, such as wide roads devoid of trees or street life, or a highway that cuts through a neighborhood.

Burgess suggests that this Aristotelian System framework can be used practically by engineers and ethicists alike and will hopefully help shift engineers beyond simply avoiding harm and liability. Take the problem of a depleted water reservoir. First, one must identify the problem—e.g., water is a non-renewable resource, and if it depletes at the current rate we will run out. Then, one must imagine the intervention to avoid the bad outcome: perhaps water system managers limit individuals’ water use. Is this a moral problem? Is it one that can be solved with an economic incentive? Does it increase happiness? Lastly, one must use system tools to model the system more accurately to understand where the feedback delays are—e.g., how do people know if they are using over their water limit? At what point do water system managers realize that there are resource problems with the reservoir and act to correct them? And what are the harms that any action may cause to other parts of the system?

System tools that capture what is going on in the system, such as behavior over time graphs, can help us to perform ‘practical wisdom.’ Again, ‘practical wisdom’ is acting upon ideas or good intentions, not just possessing them. Once we recognize that we are operating in a system, we can recognize our impacts and act upon good intentions—for example, are we just failing to promote happiness, or are we actively engaging in positive harm? Tools like system archetypes, or diagrams, can give us an idea about how the system behaves and where we should stage an appropriate intervention. At the same time, engineers and other actors must recognize that the metrics they use are not value-neutral. Engineers and others can metricize ethics to optimize what happiness means for people—e.g., maybe owning a car, or a salary increase—but applying ethics to optimize the functioning of the system should be carried out with caution. One can introduce bias if one assumes that their chosen metrics are the only ones by which people might want their system examined.

Engineering is not value-neutral and outside of philosophical exercises, engineers face competing demands and real costs associated with system changes. With ethical systems engineering, engineers are encouraged to consider a lot more than ‘doing no harm.’

**Resources**

To learn more about ethical engineering and systems thinking, explore the resources below:

* Virginia Anderson and Lauren Johnson, 1997, Systems Thinking Basics: from Concepts to Causal Loops, Leverage Networks, Acton.
* Ludwig Von Bertalanffy, 1969, General System Theory: Foundations, Development, Applications, George Braziller, New York.
* Donella H. Meadows, 2008, Thinking in Systems: A Primer, Chelsea Green Publishing, White River Junction.
* Peter M. Senge, 2006, The Fifth Discipline: the Art & Practice of the Learning Organization, Doubleday, New York.
* John D. Sterman, 2000, Business Dynamics: Systems Thinking and Modeling for A Complex World, Boston: Mcgraw-Hill Education.
* Systems Dynamics Society <https://www.systemdynamics.org/>
* Virginia Anderson and Lauren Johnson, 1997, Systems Thinking Basics: from Concepts to Causal Loops, Leverage Networks, Acton.
* Ludwig von Bertalanffy, 1969, General System Theory: Foundations, Development, Applications, George Braziller, New York.
* Donella H. Meadows, 2008, Thinking in Systems: A Primer, Chelsea Green Publishing, White River Junction.
* Elinor Ostrom, 1991, Governing the Commons: the Evolution of Institutions for Collective Action, Cambridge University Press, Cambridge.

**References**

[1] V. Anderson and L. Johnson, *Systems thinking basics: from concepts to causal loops*. Cambridge, Mass: Pegasus Communications, 1997.

[2] L. von Bertalanffy, *General system theory: foundations, development, applications*, Revised edition. New York: George Braziller, Inc, 2015.

[3] Aristotle, *Nicomachean ethics*, 2nd ed. Indianapolis, Ind: Hackett Pub. Co, 1999.