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sdm pulse

The newsletter of the Massachusetts Institute of Technology
System Design & Management program

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Tesla Motors © 2016

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For further information, visit **sdm.mit.edu**.

On the cover: Tesla's factory in Fremont, CA. During the 2016 spring tech trek, SDM fellows got an up-close look at the company's state-of-the-art assembly line. (See article on page 22.)

MITsdm

Welcome

The MIT System Design & Management (SDM) program is all about using a whole systems approach to innovation that can not only create new products and services but also improve the world. Articles in this edition of the *SDM Pulse* highlight several diverse and impressive ways in which SDM alumni and students are leading this movement. Among the highlights:

- a report on a systems approach to digital manufacturing in Chicago that is part of a nationwide initiative spearheaded by the White House;
- an essay on some technical and philosophical questions raised in Estonia during the development of information technology designed to better serve that country's population;
- an article on the business and environmental issues facing smallholders in India who are considering the transition from chemical to organic farming; and
- a look at a new way to deter some of the most recent—and deadly—cybersecurity threats.

This issue also showcases the many ways that SDM alumni and industry partners participate in cultivating and enhancing SDM's ongoing learning community—as well as information on how you can get involved. This includes:

- SDM Tech Treks (see page 22);
- SDM's annual conference on systems thinking for contemporary challenges and related event, such as back-to-the-classroom sessions and an SDM information evening (page 26);
- A HUBweek-sponsored panel on innovation (page 27);
- live and virtual information sessions for prospective applicants (visit sdm.mit.edu); and
- upcoming webinars on applying systems thinking to complex challenges in industry, government, healthcare, and more.

In addition, you will also find news about SDM's new cohort and the employment report for SDM's 2015 graduates.

As always, we hope you enjoy this edition of the *Pulse*, and we welcome your feedback and suggestions. As importantly, we look forward to seeing you at one or more of the upcoming SDM events!

Sincerely,

Joan S. Rubin
Executive Director (Interim) and Industry Codirector
MIT System Design & Management
jsrubin@mit.edu

About the Author

James A. Barkley is a director at UI LABS, one of the premier national manufacturing institutes launched under the Obama administration. He works in the Digital Manufacturing and Design Innovation Institute (DMDII), primarily on the Digital Manufacturing Commons—an open-source, next-generation platform for bringing together manufacturing-related data, tools, people, and projects in a cloud-hosted web platform. He previously served as principal engineer at The MITRE Corporation. Barkley earned a BS from the University of Colorado, Boulder, and—as a graduate of System Design & Management—a master's degree in engineering and management from MIT.

Creative Destruction* in Manufacturing: Exploring Success (and Failure) Factors in Multi-Sided Marketplaces

The challenge: *Digitize manufacturing by creating a revolutionary online collaboration and engineering platform.*

When the President's Council of Advisors on Science and Technology released its first report in July 2012 calling for the creation of a National Network of Manufacturing Innovation (NNMI), I had no idea I'd eventually be working at one of the first endeavors. Spurred by declining US manufacturing leadership, the NNMI was an unprecedented attempt by the government to stimulate a renewed, cross-sector, national effort to secure US leadership in advanced manufacturing technologies, and in his 2013 and 2014 State of the Union addresses, President Obama proposed 45 new institutes under NNMI over a 10-year period.

The Digital Manufacturing and Design Innovation Institute (DMDII) was the second or third of these institutes (Numbers 2 and 3 were announced on the same day!). Backed by a $70 million grant from the Department of Defense and operated by UI LABS, a Chicago-based 501c3 specializing in public-private partnerships, DMDII's mission is to transform American manufacturing by ushering in the digital revolution through

- sponsored research and development,
- outreach and education, and
- technology transition and commercialization.

In February 2015, I joined the DMDII ranks with the goal of bringing to fruition a very special software capability envisioned as a cornerstone of DMDII. The Digital Manufacturing Commons (DMC) is a free and open-source software project to develop a collaborative engineering platform that will enable plug-and-play functionality across the entire product lifecycle, from conceptualization to manufacturing and services.

With a career background in software and defense systems, as well as recent experience in manufacturing research and development, I was up for the engineering challenge. The business challenges, however, were a vexation. Questions included:

- In a huge industry with many established players undergoing such massive disruption, how could product adoption be ensured?
- What would be the operating costs? and
- Were there potential revenue streams that would offset those operating costs and still be compatible with our mission and values?

** The term "creative destruction" is taken from the work of Austrian-American economist Joseph Schumpeter. It is a theory of economic innovation and the business cycle that describes how new economic orders are continually created and prior economic orders are continually destroyed.*

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Like any good, data-driven SDMer, I turned to the obvious answer: modeling and simulation! But what to model? First, I needed to do some research.

The approach: *Modeling and simulation of key factors revealed in research.*

After an initial round of research, I realized that the business vernacular for what I was building is "multi-sided platform" (MSP). An MSP is exactly what it sounds like: a platform that brings together and perhaps even brokers transactions between two or more groups of customers that have interdependencies. Examples include Uber, Facebook, Airbnb, Groupon, and so on.

In traditional product adoption, reinforcing network effects are still the most powerful forces we know. These can be modeled in a relatively straightforward mathematical way using logistic growth models, or more commonly, the Bass diffusion model. In MSPs, however, there are indirect—sometimes called "side-channel" or "cross"—network effects, which lead to much less stable or predictable dynamics. My hypothesis and conceptual framework (Figure 1) reflects my understanding that there must be a key set of levers to influence, or at least predict, these types of system dynamics.

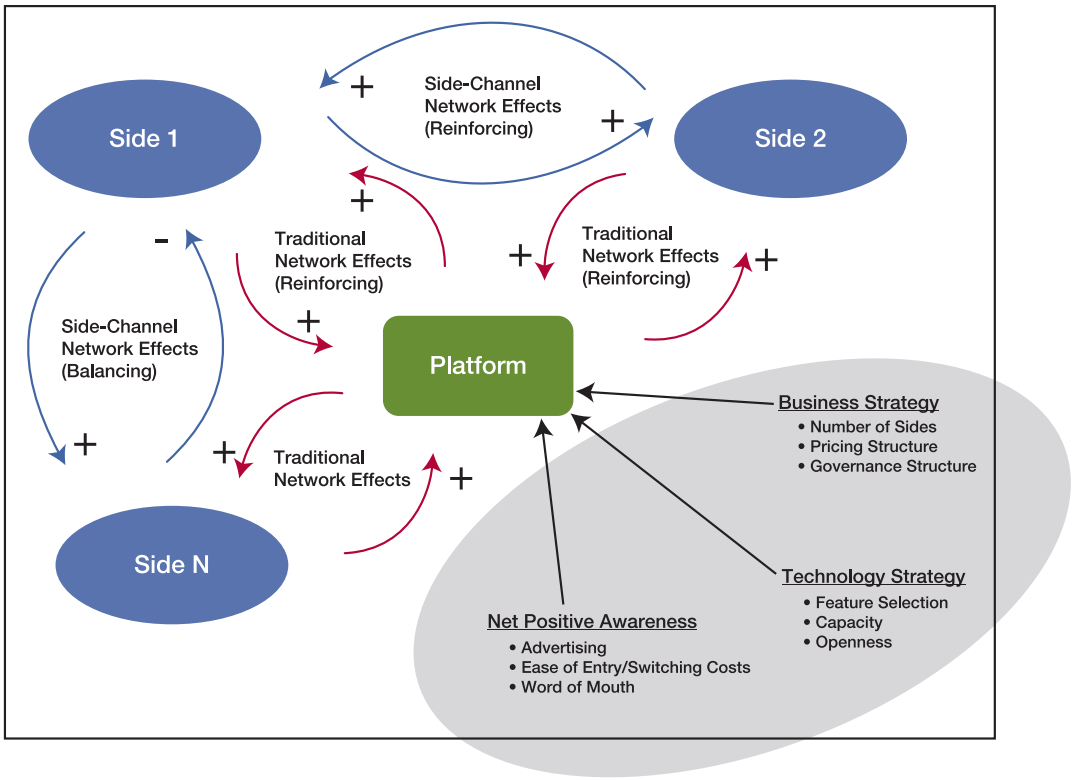

Figure 1. This is the conceptual framework for multi-sided platforms (MSPs) and key governing factors. The inherent difficulty in understanding MSPs stems from side-channel network effects.

Figure 1 shows how the side-channel network effects can cause inherent difficulty in understanding MSPs. To illustrate, let's take the case of Facebook. The more users (Side 1) that join, the more users are likely to join, and traditional reinforcing network effects apply. The more businesses (Side 2) that join, the more users want to join and vice versa, thus showing that positively influencing side-channel network effects are at play. However, the more advertisers (Side N) that join, the less users want to join, the less some business want to join, and the more other business want to join.

The tools: *Literature review with concept tagging and system dynamics modeling with sensitivity analysis.*

Armed with the conceptual framework, I was now prepared to start modeling. I chose a system dynamics representation, loaded up my Vensim DSS software, and began. The core structures were straightforward and based on the Bass diffusion model of adoption.

Next I performed a perspective decomposition on the initial core framework, assessing different lenses through which to view a multi-sided platform and leading to the breakdown of the literature into several distinct categories. In the end, books, papers, journal articles, interviews, etc., were reviewed and separated into four major categories:

- crowdsourcing and innovation,
- multi-sided platforms,
- psychology of user motives, and
- open source and multi-source.

These categories ultimately drove the keyword and search criteria for ongoing review.

More than 74 sources were mined in total. As each article was reviewed, key influencing factors that could be modeled were annotated and extracted. Although a formal codebook was not developed, factors were sorted into higher-level "codes" that could be applied across the different literature sources. This process is sometimes referred to as "coding" and is a classic approach to the systematic coding of text in qualitative data analysis.

The results: *A prioritized list of variables mapped into a system dynamics model and validated against Twitter and Facebook data.*

Each code appearing in the references is counted up by category and then summed across all categories to show a final scoring matrix, which can be seen in Table 1.

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Parameter	Crowdsourcing & Innovation	Multi-Sided Platforms & Markets	Psychology of User Motives	Open Source & Multi-Source	Rank
Incentives	14	2	4	4	24.0
Crowd Selection (Diversity, Specialization, Population Size, etc.)	13	5	0	1	19.0
Intellectual Property	5	3	3	5	16.0
Communication Among Crowd	7	3	2	4	16.0
Charging/Pricing Model	5	3	2	5	15.0
Transparency/Openness	0	4	3	6	13.0
Platform Selection (Feature Selection, Advanced Capabilities, etc.)	9	3	0	0	12.0
Profit	3	3	3	1	10.0
Low Barrier to Entry	0	2	2	5	9.0
Quality	5	1	0	3	9.0
Operating Costs	2	1	2	3	8.0

Table 1. An evaluation of the top 11 key factors influencing a multi-sided platform produced this ranked list.

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Not all of the variables lent themselves easily to variable representation, but over many iterations of refinement, abstraction, variable decomposition and recombining, I arrived at a final model.

In order to validate and assess the model, several experiments were done comparing Facebook and Twitter historical data on financial performance and user growth with simulation predictions. The simulation of Facebook user growth, for example, lined up very nicely with actual historical data, indicating our model was quite accurate.

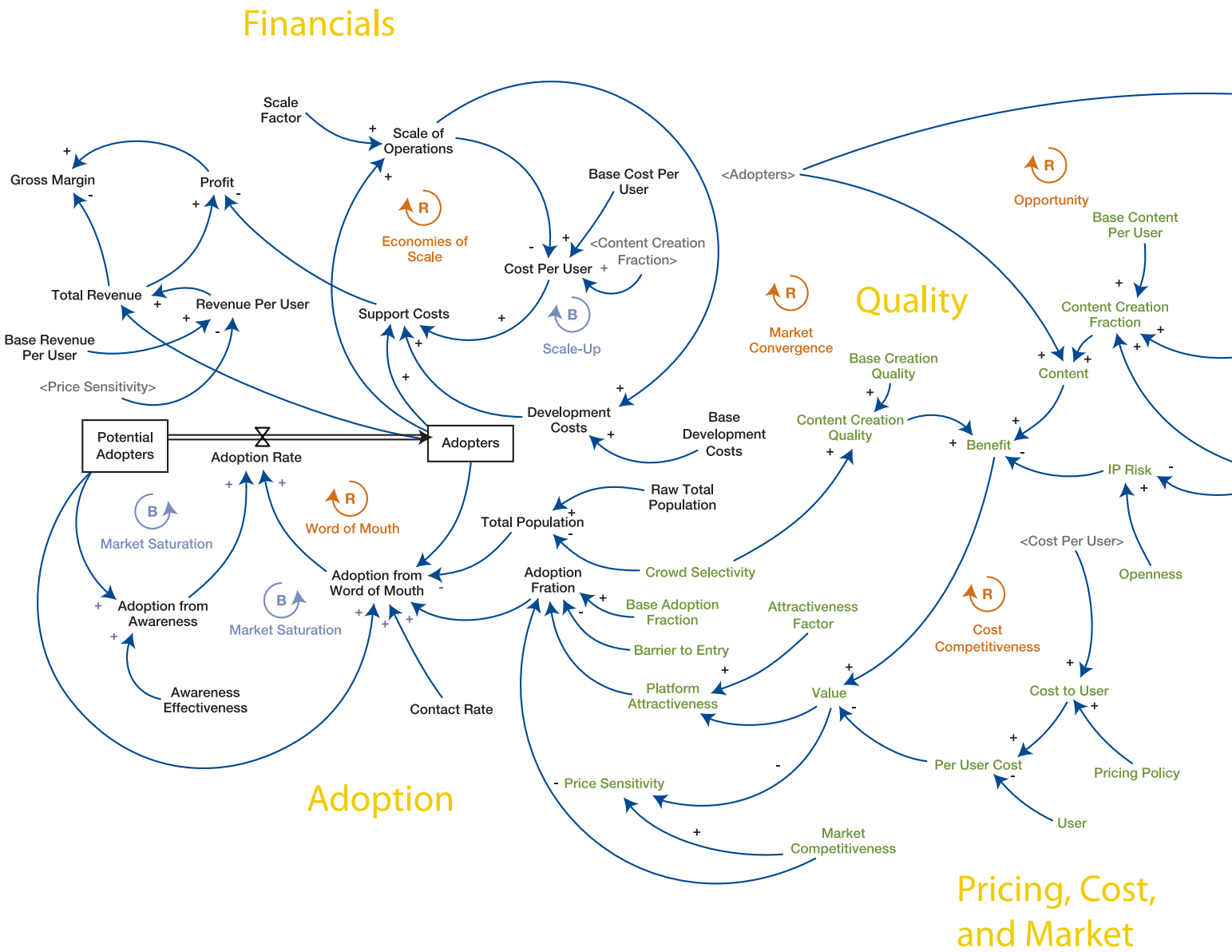
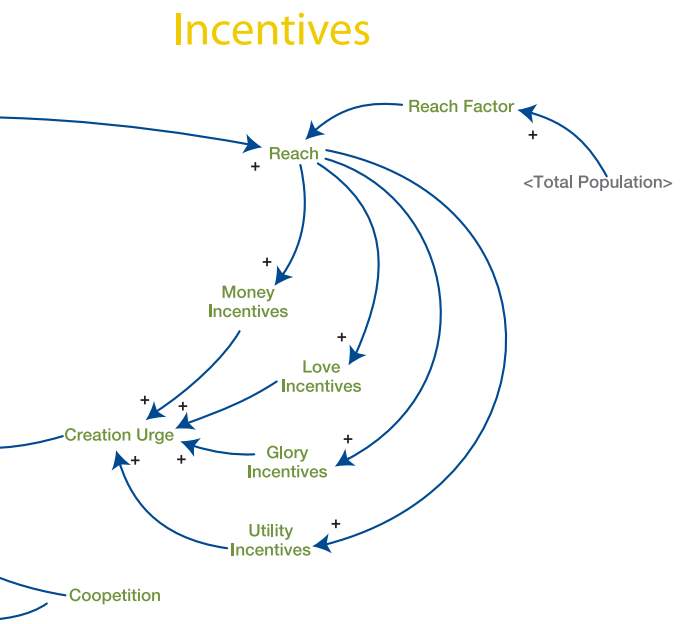


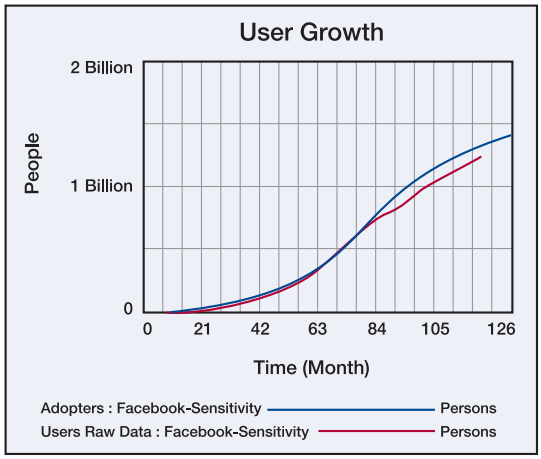
Figure 2. The final model of key factors for multi-system platforms. Classic network effects are shown in the Word of Mouth and Market Saturation loops, while more subtle factors such as content quality (important for Wikipedia, but not for Facebook!) and user incentives and reach are seen more in the Opportunity and Market Convergence loops. Pricing policy, cost per user, and revenue per user are some of the core financial drivers.

Convinced of the model's efficacy, I proceeded to devise a set of experiments based on a hypothetical manufacturing-focused MSP. This included development of a user interface where I could easily manipulate the exogenous variable parameters and observe the effect on key outputs.

Finally, I performed an in-depth sensitivity analysis on all key variables to understand which ones were most influential.

Next steps: Interpret the results and use the model for the digital manufacturing platform of the future.





The sensitivity analysis revealed that adoption fraction and contact rate are the most important variables; however, these are not things that can be directly controlled. Therefore, the key elements to focus on for understanding, forecasting, or optimizing an MSP in the wild are those that are sensitive but controllable:

- coopetition (cooperative competition),
- content per user,
- awareness effectivity (a measure of how effective marketing and advertising are at driving product adoption),
- revenue per user, and
- cost per user, market competitiveness, and base creation quality.

Generalizing this finding reveals an important lesson from this work: The indirect network effect factors often manifest themselves as coefficients to traditional network effect variables. For example, "incentives" was the top factor from the literature review, but its real impact is to make the platform more attractive through content creation and reach. This "opportunity loop" is a reinforcing power that ultimately amplifies the percentage of people who will adopt the platform through word of mouth.

I still use this model and the lessons learned from the effort in my work at DMDII. As we continue to build the Digital Manufacturing Commons, we are constantly evaluating decisions and tradeoffs such as barrier to entry, governance and policy restrictions, and user interactions. Find out how we're doing at projectdmc.org!

References are available on request.

About the Author

Andres Kütt, is the chief architect for the Information System Authority of Estonia. During the course of his career, he has built websites, bank and taxation systems, and peer-to-peer telephony networks. For the past 10 years, his main focus has been on software architecture. He holds a BS in mathematical statistics from the University of Tartu, an MBA from Estonian Business School, and an MS in engineering and management from MIT as a graduate of System Design & Management.

What Is a Country? What Is a Citizen? How Estonia Uses Systems Thinking to Update Mental Models and Reflect Today's New World

The challenge: Since the Thirty Year's War ended with the Peace of Westphalia in 1648, world affairs have been organized primarily according to the relationships of states and countries. Traditionally, states and countries have been defined by several characteristics, including:

- sovereignty over a discrete territory;
- an organized and relatively complex form of governance; and
- a population that shares a national identity.

While this definition is still largely valid, the idea of what a state or country actually is today is rapidly and continually evolving thanks to information technology (IT). IT has changed how we communicate, work, and live to such a degree that many of us now see ourselves as more than citizens of a country; we are citizens of the world.

This major paradigm shift presents significant challenges because it creates tension between governments, which continue to act according to their historical modus operandi, and the societies they serve, whose identities and needs are rapidly changing due to technology and globalization. This problem is especially serious for governments of small countries because they lack significant leverage to influence global trends but are still under pressure from their citizens to be relevant and provide modern services.

Estonia is one of these countries. A tiny nation situated at Europe's northeastern edge, it has no significant natural resources or geopolitical advantages. A vital question for its government is not just how to survive but, more importantly, how to better serve its people—who now study, work, and socialize in a wider, more complex world.

The approach and tools: To determine how Estonia could best serve its citizens, it was important to begin with the right questions, no matter how dauntingly complex—or seemingly simple—they appeared. In the Information System Authority of Estonia, we have found systems thinking and the toolset of system architecture to be well-suited to addressing challenging questions. Our agency, a relatively small team of software architects and cybersecurity specialists, is specifically tasked with developing the architecture of Estonia's information system and leading its protection.

The first question we asked ourselves was, "What is a country?" We quickly learned that, because "country" is an abstract and multifaceted word, it can have different meanings and manifestations to various stakeholders. Accordingly, different concepts can lead to different

understandings of which particular observable manifestations are essential to a country's form. For example, some might consider a country to essentially consist of the tax office, because it funds national services, while others might consider the education system more fundamental because of its role in shaping national identity. We thereby learned an important lesson: It can be easier and more productive to address function first and consider form later.

While we found many different viewpoints about what a country's function is or should be, we also discerned that a society can employ a wide range of mechanisms (such as public debate, elections, and so forth) to develop and adopt a shared understanding of its state's function. In our case, the key function of the Republic of Estonia as stated in our 1992 constitution[1] is "preservation of the Estonian people, language, and culture." The US Constitution, on the other hand, states very different goals: "to establish Justice, insure domestic Tranquility, provide for the common defence, promote the general Welfare, and secure the Blessings of Liberty to ourselves and our Posterity."

Understanding the perceived function of the state led us to postulate various mental models for how best to provide these functions. In a healthy society, mechanisms must exist for distilling a consensual core concept of the country. This is where system architecture becomes invaluable.

The most common elements of the old and problematic nation-state definition—territory and governmental organization—come from shared, but often outdated, understandings about what constitutes a state. For any country today to make sense and add value to its citizens, the concept of what it is and what it does must be updated. Given that the traditional concept is made concrete by complex political and administrative mechanisms, creating this change is not easy.

Estonia has succeeded in doing this, at least partially, because the country decided to take the route of radical, rapid reforms after it regained independence in 1991. We have adopted a new concept of the nation-state that incorporates a third element into the definition of a country: the information system (see Figure 1).

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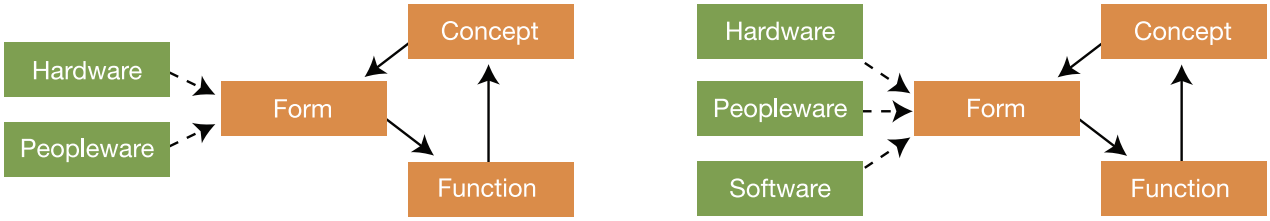

Figure 1. A system is defined via a feedback loop of concept, form, and function. For countries, the form has traditionally included hardware and peopleware—in other words, physical structures and human endeavor. Estonia has expanded this definition (left) to incorporate information systems as integral part of what a country is (right).

[1] www.constituteproject.org/constitution/Estonia_2011?lang=en

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As in any other part of the globe, government processes and regulations in Estonia are difficult, if not impossible, to execute without information systems. For example, since 2010, an electronic database has constituted the ultimate source of law in Estonia; no official physical copy of the current law is available. The database contains all laws and regulations going back to 2002.

As in many other countries, this choice was both driven by necessity and addressed with sensitivity to the important philosophical questions that can drive the development of operational systems that support "who we are and who we are becoming, not simply who we were." Estonia's information systems and technical solutions are neither innovative nor clever, but they have been deeply woven into the fabric of how the government now operates. This high level of integration enables the government to change, transform, and strive for efficiency.

Key examples of how IT is redrawing the lines of government in Estonia include:

- E-residency—Estonia offers a transnational digital identity service that enables anyone to administer a location-independent business.
- Data embassies—Estonia is planning to store critical government data on protected remote servers to ensure the state can continue to function even in the event of natural or man-made disaster.
- X-Road—This integration tool enables all of Estonia's many databases to work together smoothly. The tool makes it possible to write to multiple databases, transmit large data sets, and perform searches across several databases.

Developing such functionality naturally raised the question of how the word "citizen" is defined in today's world. The basic tools of system architecture and systems thinking, however, enabled us to reconceptualize what a "citizen" is and foster innovative thinking. A good example is the subject of residency that incorporates the new concept of e-residency. Residency is commonly bound to the two key aspects of a country and assumes a person is physically within the geographical boundaries of the state and thus subject to its administrative processes. E-residency is an unprecedented concept that expands that idea to include people who interact with our information systems but do not physically reside in the country.

This due diligence on the part of the team led to some important insights:

- *Emergence stems from form*. The decision to include information systems as an integral part of the state rather than as something that merely supports other aspects or functions of the state, has allowed new state and historically unprecedented functions to emerge. Estonia has had a well-functioning and ubiquitously used electronic identity infrastructure for more than 10 years. It was built using reasonably modern technology that is intended to scale well beyond Estonia's 1.3 million citizens. And, with a slight change in the mental models that shape our thinking about countries (from providing this technology to physical residents only to opening it up globally to virtual citizens of the country), this infrastructure can provide a completely new functionality.
- *Limitations stem from the old mindset driven by administrative and physical geography*. Questions such as the following need to be addressed: In today's world of global business, how much time does a person need to spend somewhere to be a resident or a citizen?

Neither Estonia's physical infrastructure nor its governance have the same scalability as its electronic identity infrastructure. Growing a physical organization and its processes by an order of magnitude is a grand challenge. In contrast, a tenfold growth from 1.3 million customers does not really challenge a well-designed information system. However, it's important to remember that information systems do not provide innovation in isolation. A society must be willing to change its shared conceptions about what a "state" or "country" is and does.

Next steps: Being on the leading edge of creating new mental models is both exciting and risky. Embedding innovation- and risk-prone information systems deeply into our governmental processes has brought certain risks closer to the core of governance. Neglecting to update the software on a server for a retailer is one thing, but neglecting to update the software for the legal system is a very different matter. That system constitutes the only legally significant source of law in Estonia.

An established country does not enjoy the same luxuries as a startup: It cannot fail fast when working on its core concepts. Here, the ideas and approaches of system safety have allowed us to develop resiliency strategies that advance the interests of our national security policy. For example, Estonia's voluntary (but very popular) militarily organized national defense organization has a branch specifically focused on cybersecurity. That team is tightly integrated into civilian processes that are focused on the safety and security of the country's information systems.

People frequently ask for the "e-residency architecture," and the answer just as frequently disappoints. There is none. We are not building anything specific, merely extending and improving existing systems and adjusting processes. There are already signs that this approach can lead to more innovative ideas about how government can be more relevant in the digital age—for example, we are working on the above-mentioned plan to use data embassies to virtualize our country.

The systems thinking approach to digital government has important implications for how countries think about who they are and what they can be. The bottom line is that it is not enough to spend money on building systems. While such expenditures can make existing processes more efficient and less costly, the real benefits of systems thinking will be realized only when the core conceptions of what a country is are open for debate and re-examination.

For governments everywhere, huge challenges loom. But with the help of systems thinking, these can be turned into steppingstones toward a much more inclusive and profitable—not to mention interesting—future.

About the Author

Sarah Nolet is the founder of AgThentic, an innovation and sustainability consulting firm for the food system. As a graduate of System Design & Management, she holds a master's degree in engineering and management from MIT, where she ran the Food and Agriculture Club, cofounded the MIT-Rabobank Food and Agribusiness Innovation Prize, and wrote her thesis on "Accelerating Sustainability-Oriented Innovations in Agribusiness." She also holds a BS in computer science and human factors engineering from Tufts University.

Helping Smallholders in India Transition from Chemical to Organic Farming: Do Things Have to Get Worse Before They Can Get Better?

The challenge: Smallholder farmers (those who own less than 2 hectares of land) comprise about half of India's population, half of the country's employment, and 18 percent of its income. They also account for more than half of India's hungry and poor.

Conventional farming, which uses technologies such as synthetic fertilizers and pesticides, is today the status quo on such farms, but chemical-based agricultural practices have become controversial in terms of efficacy, economic well-being for farmers, and environmental sustainability. While such practices have helped farmers increase their income, over-reliance on chemicals can cause:

- soil erosion,
- water pollution,
- air pollution,
- loss of biodiversity, and
- damage to human health.

Organic farming, in contrast, can improve the health of the soil and ultimately provide benefits both to the environment and to farmers. The rich nutrient composition within organic fertilizers increases both biophysical (e.g., soil organic matter) and biological (e.g., biodiversity and biomass) aspects of soil health.

Even so, less than 1 percent of India's land is farmed organically. Our research endeavored to determine why that is.

The approach: One hypothesis is that smallholder farmers are concerned that that the transition to organic farming will bring "worse-before-better" (WBB) results. Specifically, they fear that switching to organic methods will initially cause crop yields and income to fall—even if they eventually equal or surpass historical results.

One fundamental reason farmers fear a WBB scenario may be the disagreement about how farm productivity differs under conventional vs. organic systems. Conflicting current research findings on yield potentials underscore the subtleties of this question. For example:

- Some nongovernmental organizations (NGOs), environmental activist groups, and scientists claim that under optimal organic practices, a farmer can both increase profits and improve environmental health.[1]

[1] Tej Pratap and C.S.Vaidya (2006), *Organic Farmers Speak on Economics and Beyond*, Westville Publishing House, New Delhi.

- Other research[2] has found that organic farming systems are inherently less efficient than those that are chemical-based. These researchers believe that an organic farmer can only achieve economic advantages with subsidies, price premiums, or the adoption of animal husbandry.

Moreover, the adoption of organic farming can be inhibited by informational, social, and market-related factors, including:

- lack of awareness about the pros and cons of conventional and organic farming systems;
- inadequate access to technical know-how about new approaches and marketing opportunities;
- the unavailability of materials needed to create organic fertilizer; and
- negative perception of organic systems.

To our knowledge, no systematic study exists that synthesizes how these factors relate to the feared WBB scenario. Therefore, our research asked: *Under what conditions is the transition from conventional to organic methods most favorable to the farmer?*

Our effort is a step in the direction of assisting policymakers and NGOs in enabling smallholder farmers to transition more easily to sustainable agriculture that is also profitable.

The tools: First we reviewed current studies on organic and conventional farming systems. Then we traveled to Haryana, India, to conduct interviews with experts and farmers who were using organic, conventional, and mid-transition methods. We then used the data to build a system dynamics model that shows the necessary conditions for a farm to exhibit worse-before-better behavior during the transition from conventional to organic farming.

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Farmers in Haryana, India, serve as a focus group for research on farming methods.

[2] Uematsu, H., & Mishra, A. K., (2012). "Analysis: Organic farmers or conventional farmers: Where's the money?" *Ecological Economics*, 7855-62.
Giovannucci, D., (2005). Evaluation of Organic Agriculture and Poverty Reduction in Asia, Rome: IFAD Office of Evaluation.
Nemes, N. (2009). Comparative Analysis of Organic and Non-organic Farming Systems: A Critical Assessment of Farm Profitability. Food and Agriculture Organization of the United Nations, Rome, June 2009.

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We analyzed the model to understand how factors such as cost of organic farming, time to revive soil health after over-fertilization, and the rate at which land is converted to organic farming could be used to help smallholder farmers transition to more sustainable practices.

The results: Analysis of the model shows how excessive chemical use can trigger adoption of organic practices and reveals the associated WBB dynamics that occur during the transition to organic farming. The following steps are typical:

- Farmers turn to organic methods only after soil health has become degraded.

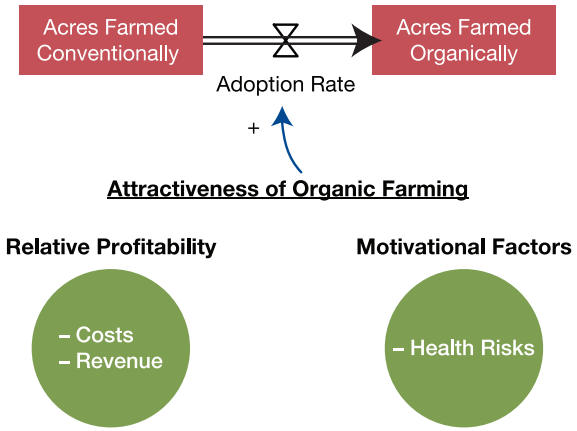


Figure 1: The relative profitability of organic farming vs. conventional farming—including costs and revenue, as well as motivational factors such as perceived health risks from exposure to chemicals—influences a farmer's decision to transition all or part of his land from conventional to organic farming practices.

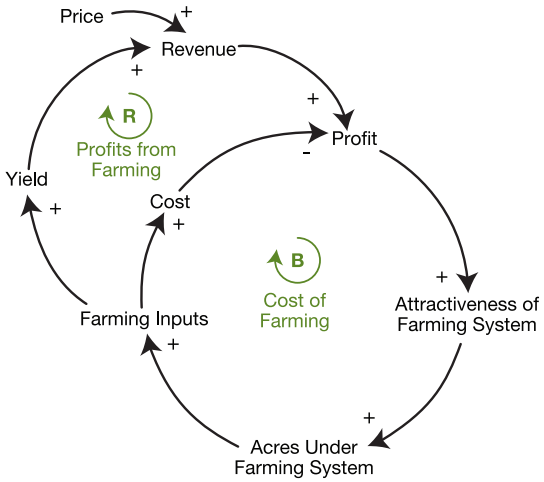
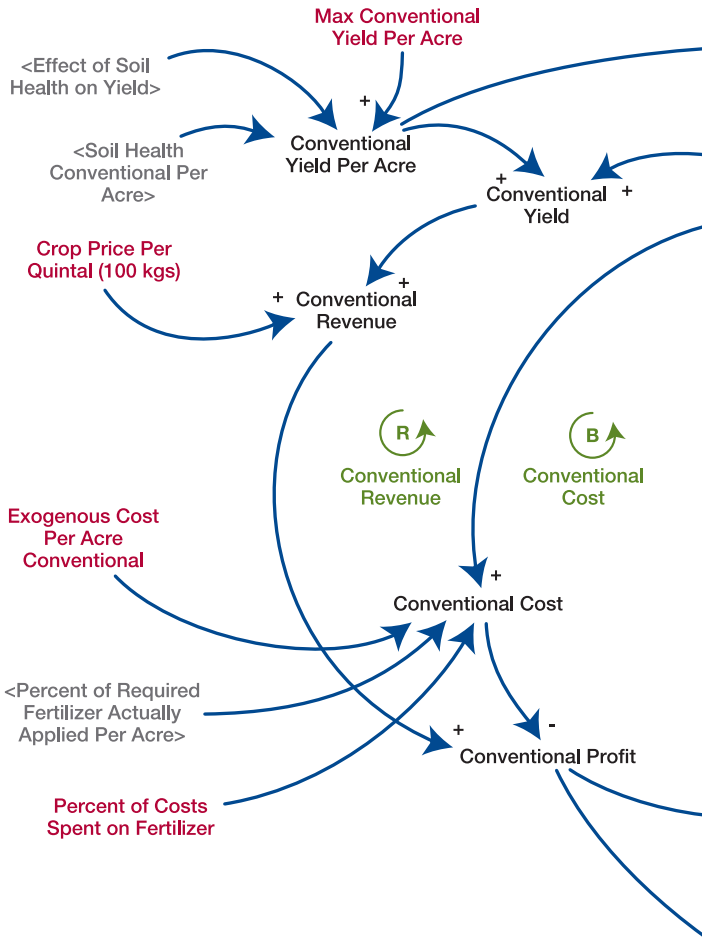


Figure 2: Two loops explain the key economic factors of farming. The Cost of Farming loop is a balancing structure: As more money is spent on inputs, costs increase and profits decrease. The Profits from Farming loop is a reinforcing structure: As yields increase, profits also increase, and the attractiveness of the current farming system (conventional or organic) increases, causing the farmer to continue farming under the same paradigm.



- Initially, yields suffer and profits decrease because it takes time for the application of manure to replenish the depleted organic carbon.
- Ultimately, effective use of manure-based fertilizers restores soil health and increases yields.
- As soil health recovers, organic yields surpass previous conventional yields, and farmer profits recover.
- As more land is moved into organic practices, profits eventually exceed pre-transition levels.

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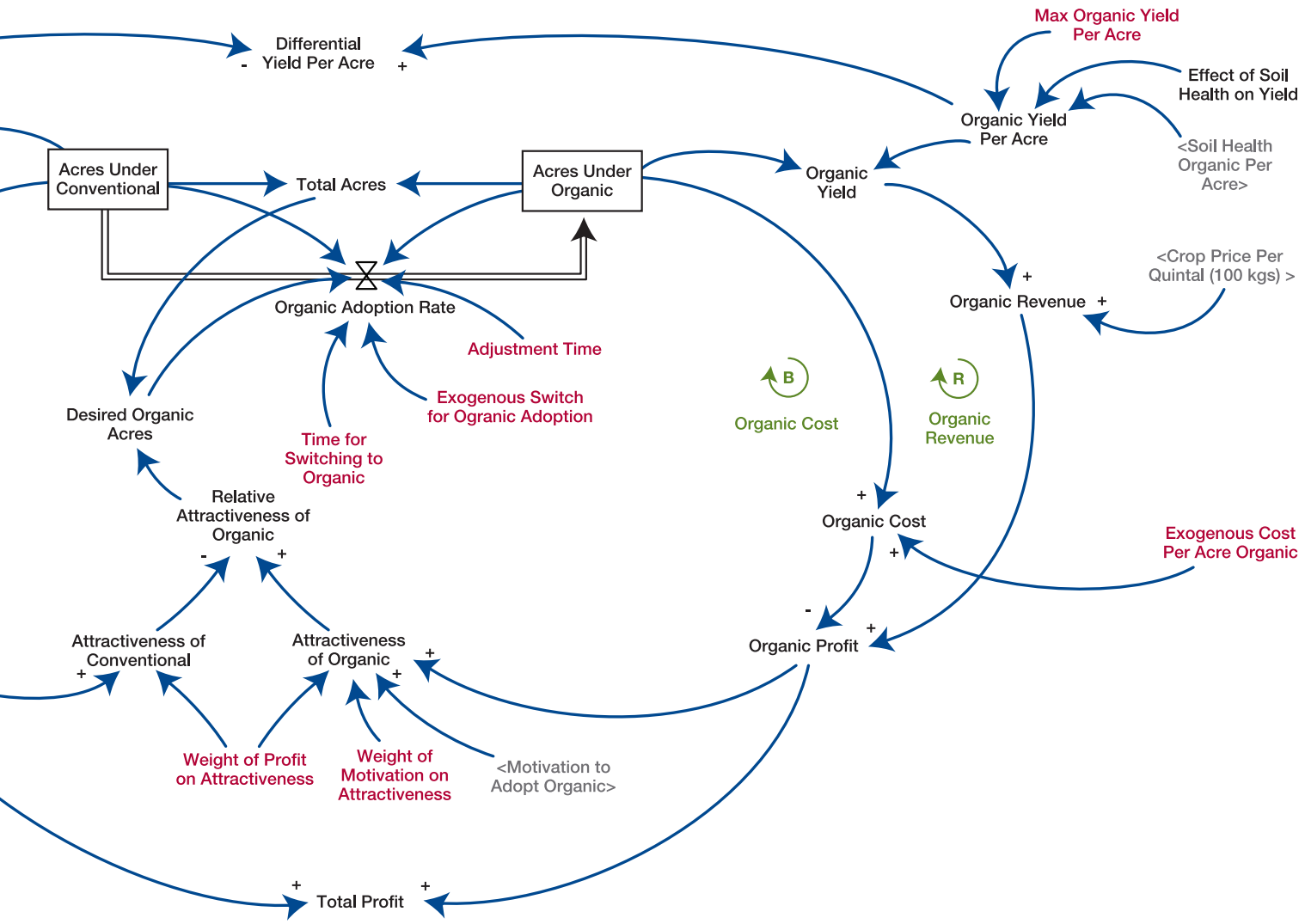

Figure 3: This figure presents the main aspects of our full system dynamics model of the adoption of organic farming. The left side of the model handles conventional farming factors, and the right side handles organic farming. The variables in red are exogenous—here we used data to set these values and test and calibrate our model. The gray variables are pulled from a secondary page of the model, where we model out the dynamics of fertilizer application and soil health. Our full conference paper explains the assumptions, calibration settings, and key structures in detail.

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Figure 4 shows how this dynamic plays out in a base case, revealing the duration and depth of the WBB trough.

Our research showed that a viable transition to organic farming depends upon organic farming conditions and practices, including:

- per-acre cost of organic farming,
- recovery time for soil health, and
- land conversion rate.

Figure 5 shows the impact of these factors on the duration of the WBB period (i.e., time to return to pre-transition profitability, shown on the X axis) and depth (i.e., loss in profits, shown on the Y axis).

Effective application of farming practices and optimal selection of inputs (such as fertilizer) can improve soil health (represented by blue diamonds) and thus reduce both the depth and duration of the WBB period. Similarly, decreasing the cost of organic farming (represented

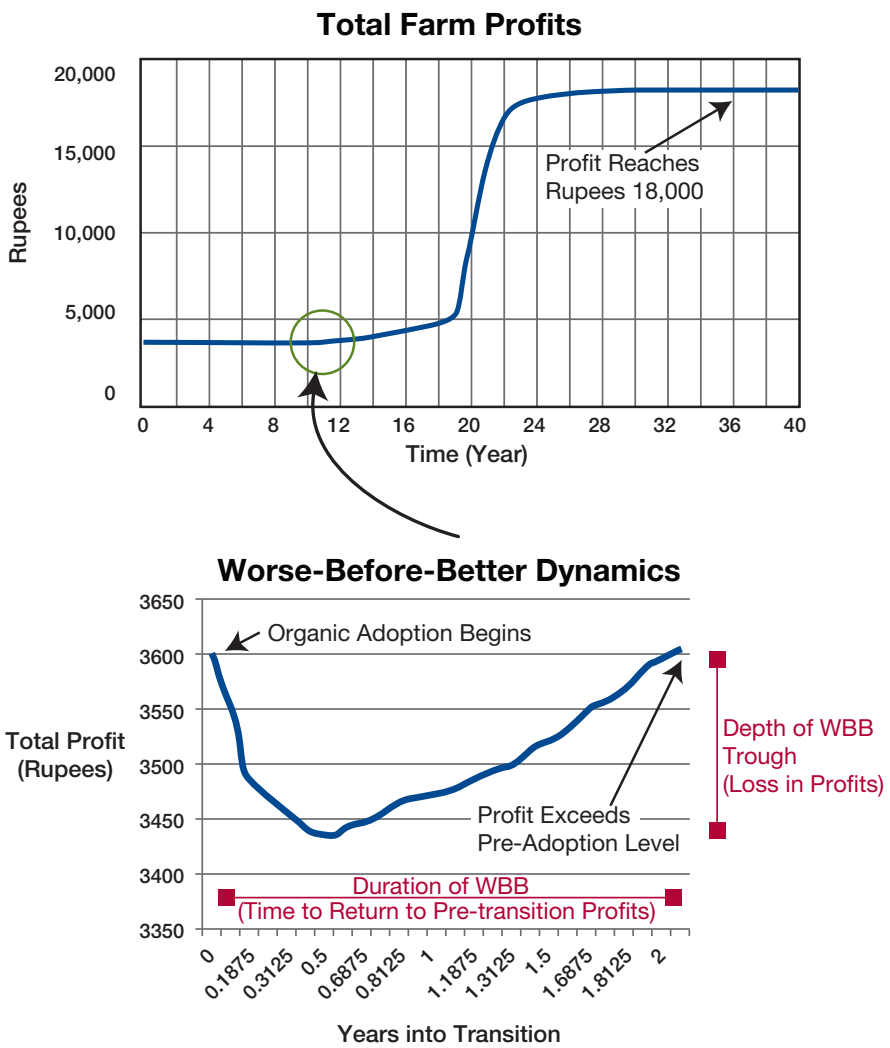

Figure 4: These charts reveal the worse-before-better (WBB) dynamics of adopting organic farming after excessive fertilizer use. The top chart shows the WBB duration—the time it takes for total profit to equal or surpass its pre-adoption value. The bottom chart shows the depth of the WBB trough—the difference between total pre- and post-adoption profits.

by the red squares) can improve profitability during the WBB timeframe. Finally, smallholder farmers can impact the depth and duration of WBB by controlling the rate at which they adopt organic practices (represented by the green triangles). Adopting organic practices more slowly than the rate at which soil health develops will increase the duration but decrease the depth of the WBB scenario, while a faster adoption will decrease the duration but increase the depth.

Finally, while organic farming may become attractive for non-economic reasons, a farmer's motivation must be sufficiently strong for the transition to be made successfully. Abrupt changes in farming practices can lead to significant losses (i.e., deeper WBB trough), while transitioning at an appropriately slow rate will keep overall profits higher. Thus, voluntary transitions that are personally motivated are preferred over those prompted by problems related to excessive chemical fertilizer use.

Overall, this research reveals that, while organic farming promises environmental and health benefits, a profitable adoption of organic practices requires understanding the economics of the transition and managing them systematically.

Next steps: In India, farmer behavior can be influenced by numerous context-dependent factors. Ultimately, however, each individual farmer decides how to allocate his land along the spectrum of available agricultural practices. Since these decisions collectively have a significant global environmental impact, conditions must be created for farmers to perceive the transition to organic farming as economically attractive and viable. Policies and training programs are needed to help farmers understand the necessary tradeoffs as well as to create optimal conditions to enable them to transition to organic farming with minimal WBB repercussions.

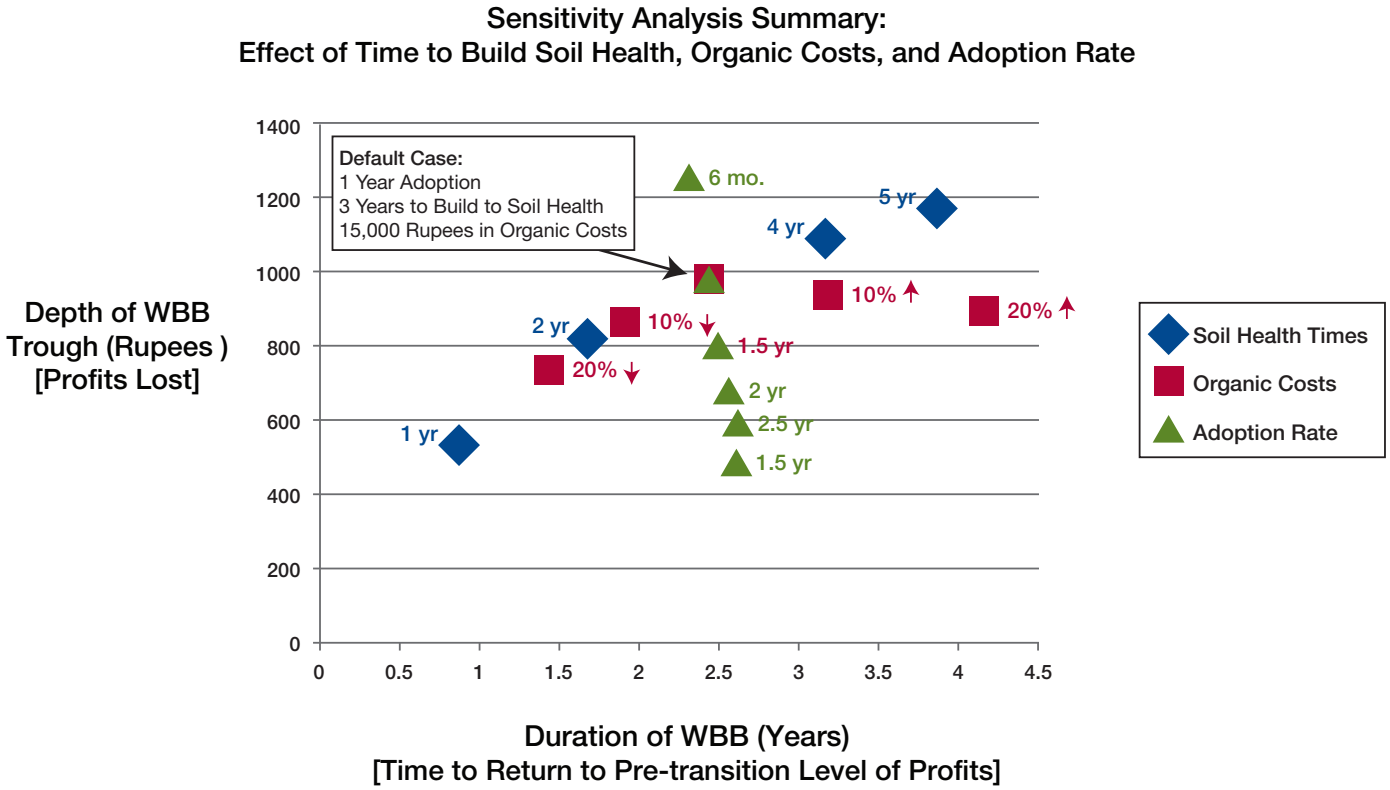

Figure 5: This chart shows the effect of soil health development time, organic farming costs, and adoption rate on WBB depth and duration.

About the Author

Charles Iheagwara, PhD, is a customer solutions advocate and security solutions consultant at Cisco Inc. Previously, he served as managing director at Unatek Inc. and as a consultant in various capacities at Grant Thornton, KPMG, Lockheed Martin, and Edgar Online. He holds a PhD from the University of Glamorgan in the United Kingdom and, as a System Design & Management alumnus, an MS in engineering and management from MIT. He also earned an MS in mineral engineering from the University of Minnesota and a BS and MS in metallurgical engineering from Russia's Moscow Institute for Steel and Alloys.

Using Systems Thinking to Assess and Address Cybersecurity Challenges

The challenge: Cybersecurity is a growing industry, with a market expected to expand to over $120 billion by 2017. The proliferation of product offerings provides companies with a wide range of security options but makes it increasingly difficult to assess which product best suits specific intrusion-prevention needs.

Users therefore need a method for:

- acquiring insight into the inherent characteristics and modes of operation for a wide variety of cybersecurity products;
- eliminating the pain points associated with choosing the wrong products;
- preventing the disastrous consequences of failing to detect and prevent intrusions; and ultimately
- meeting the intrusion prevention goals unique to their specific enterprises.

The approach: An SaaS application/tool has been developed to allow users of intrusion-prevention products to customize a business case analysis for any deployment and target environment or market. The patent-pending tool IntrusionPoint™ accepts a wide range of market data, technical parameters, and business/financial and service planning inputs that users can tailor to their own deployment plans. It simulates network deployment and operations using a variety of technical, environmental, and service plans and produces a detailed analytical report, analytics output graphs, and key technical, deployment, and implementation metrics.

The tools: The systems thinking mindset central to MIT's System Design & Management (SDM) program, as well as several systems engineering tools commonly taught in SDM were employed to develop the application. The process included:

- defining and designing a system architecture to encapsulate the different modular system subcomponents;
- conducting a system dynamics analysis of the various factors that could affect the system in either a positive or negative direction;
- developing an information flow schema;
- developing an algorithm that performs mathematical computation using the system input data to produce a set of desirable system outputs in the form of decision-making intelligence reports, analytics, and visual charts;
- developing the system analytics and visualization subsystems; and
- developing a web portal.

The results: The IntrusionPoint application performs artificial intelligence decision-making analysis of enterprise intrusion-prevention solutions, providing a computer-implemented method for evaluating the suitability of cybersecurity products for any particular user.

The method accomplishes the following tasks:

- obtaining weights representing the relative importance of a plurality of attributes related to intrusion-protection systems;
- obtaining a plurality of attribute scores for each of the plurality of attributes related to intrusion-protection systems; and
- calculating a weighted sum of the plurality of attribute scores based on the weights.

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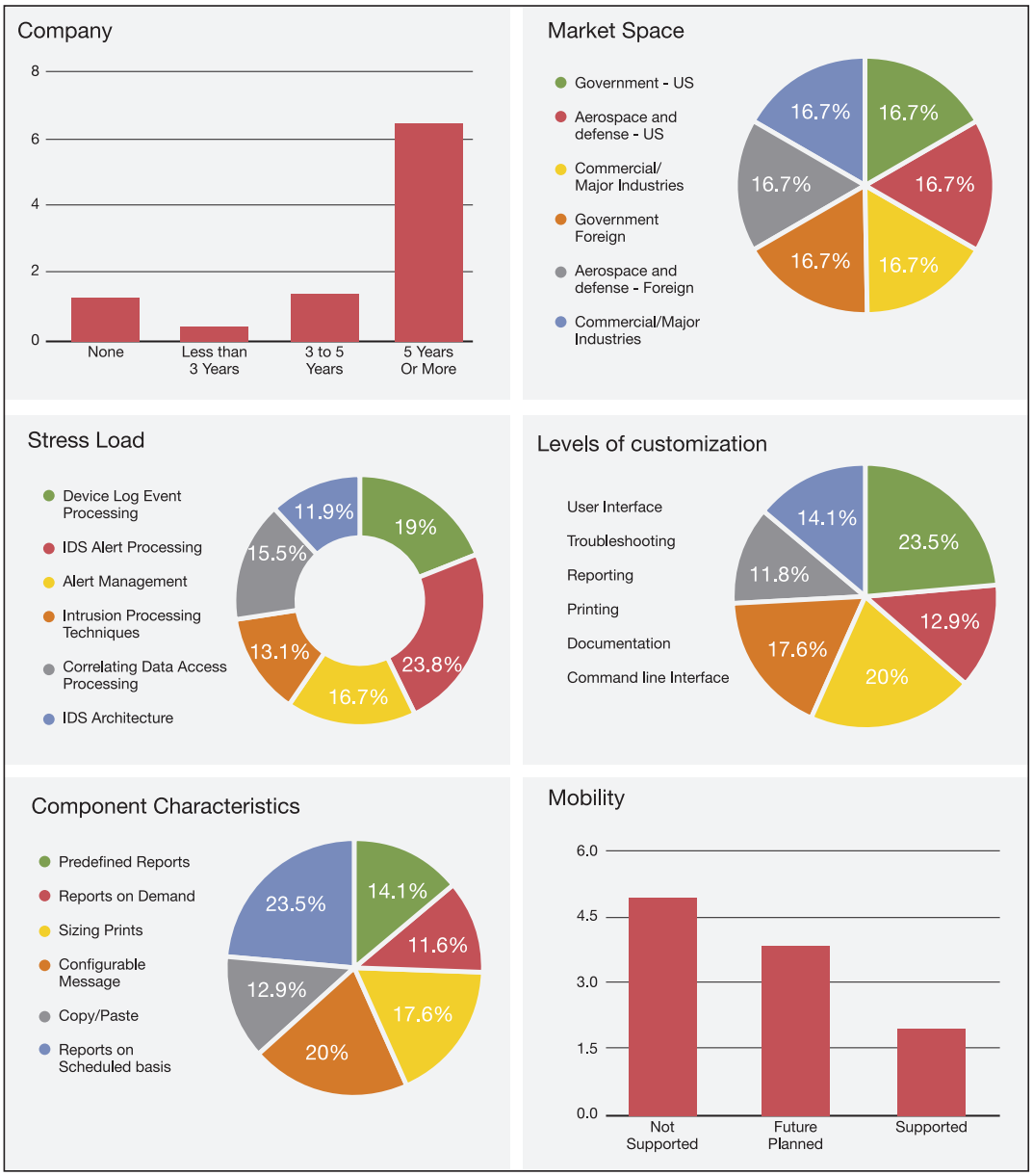

Figure 1. The charts above show a sample of analytics produced for a user of the IntrusionPoint tool.

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The tool's logical design construct and implementation provides a variety of analytics and visualizations from which end users, product developers, and vendors can gain insight into the pros and cons of each solution and thus make informed decisions related to purchases, product enhancements, and other cybersecurity tasks.

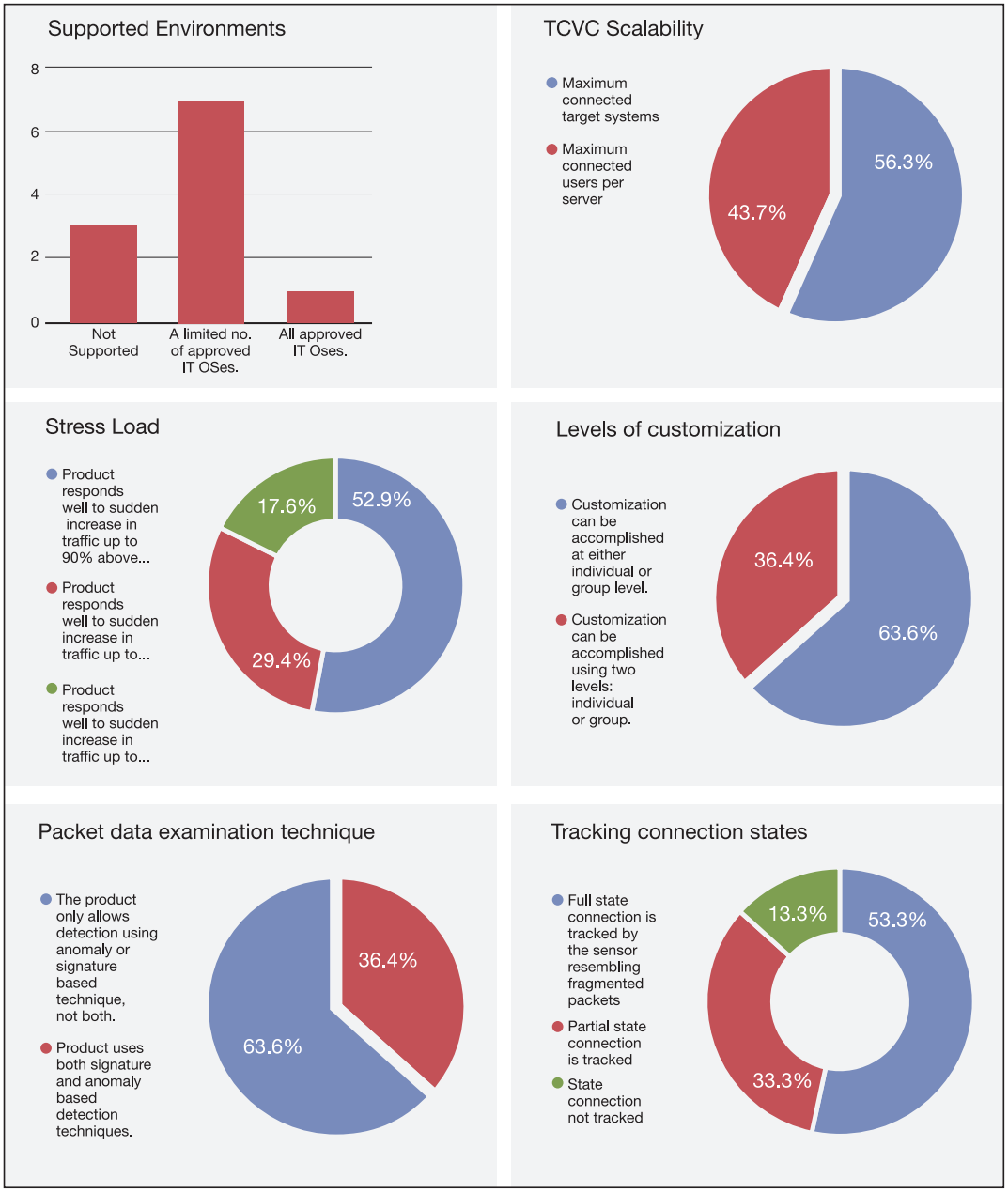


Figure 2. These charts represent a sampling of the analytics generated by the IntrusionPoint tool that enable customers to visualize the technical performance of various cybersecurity products.

Employment Report for SDM's Graduating Class of 2015

MIT System Design & Management (SDM) educates future technical leaders in architecting, engineering, and designing complex products and systems, providing them with the leadership and management skills necessary to work successfully across organizations. Graduates leave prepared to manage effectively and creatively by using systems thinking to solve large-scale, complex challenges in product design, development, and innovation. Their unique and powerful combination of technical and managerial skills equips them to lead effectively in positions throughout a wide range of industries, across all levels and functions.

SDM annually surveys members of its most recent graduating class about their career paths. The resulting report provides an overview of the employment and compensation statistics gathered from self-sponsored students who graduated from the program in February, June, and September of the preceding year. Information on the companies that hired SDM graduates is also provided.

Highlights of this year's report include the following facts*:

- 97 percent of SDM graduates who responded to the 2015 survey are employed or pursuing further educational studies;
- graduates reported an average base salary of $122,667—an increase of 52 percent over their base salaries as reported prior to entering SDM; and
- the top job functions being performed by the 2015 graduates are product development/management, engineering, and strategy consulting.

Employers who hired SDM's 2015 graduates included Amazon, Apple, Beacon Health Strategies, Boeing, Chevron, Chrysler, C3 IoT, Deloitte, Ericsson, GE Capital, Google, McKinsey, Microsoft, Tesla, Rackspace, SunEdison, and Yelp.

All information is accurate as of press time.

contact

For the full employment report or additional information, please contact Jonathan Pratt, SDM's director of career development and recruiting

jonpratt@mit.edu

SDM Tech Treks Provide Learning and Recruitment Opportunities for Students and Companies

Each year, MIT System Design and Management (SDM) runs two tech treks—one in the Greater Boston area and one in another area of the United States, such as California's Silicon Valley. These treks offer SDM fellows opportunities to engage with, and learn from, executives at best-in-class companies. Designed to build upon students' classwork at MIT, these "learning expeditions" enable fellows to tour a wide range of facilities, view product demonstrations, and engage in lively question-and-answer sessions with industry leaders. Students learn about companies' strategic, operational, and tactical challenges as well as how these are being addressed from both technical and business perspectives.

Tech treks also establish and/or strengthen relationships between MIT SDM and companies' senior leaders and recruitment professionals.

The 2016 spring trek was led by SDM '15s Vikas Enti and Kathryn Cantu, with organizational assistance from all participants. Attendees included 26 SDM master's and certificate program students, four members of the Integrated Design and Management track, Professor Warren Seering and Lecturer Bryan R. Moser; and several SDM staff members—Joan S. Rubin, executive director (interim) and industry codirector; Jonathan Pratt, director of recruitment and career development; Naomi Gutierrez, career development and alumni associate; and Amanda Rosas, logistics.

SDM Tech Trek goals:

- Gain exposure to companies across a wide spectrum of industries, sizes, and stages of growth.
- Learn about the complex challenges these companies are facing—and their approaches to solving them.
- Hear business leaders discuss how they are managing growth.
- Build a network of contacts for future projects, internships, and recruiting.
- Explore different company cultures to understand how individual working styles might fit future job opportunities.

Companies visited:

- Amazon Fulfillment Center
- C3 IoT
- Google
- Tesla Motors
- Apple
- E&J Gallo Winery
- Intel Corporation
- Visa Innovation Lab

Trip highlights:

- At the Amazon Fulfillment Center, the group was given the chance to see robotics technology in operation at one of Amazon's largest fulfillment

Google

Intel Corporation

Apple

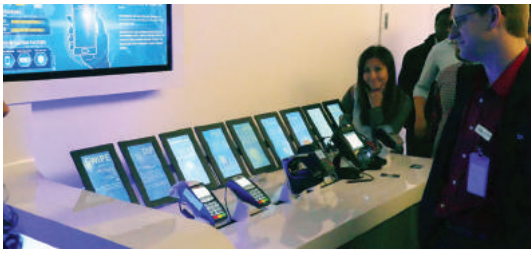
Amazon Fulfillment Center

centers in the United States. This visit, which followed a fall SDM Tech Trek to Amazon Robotics, enabled students to see the impact of leadership decisions on a full range of workers—from hourly line employees up to senior management—as the center scaled up over time.

- At Apple, students were given an overview of the company's product management system and learned how product teams are developed.
- C3 IoT offered students a real-world example of how growth can open up new market opportunities—particularly with guidance from experienced leadership. The company's expansion led to a rebranding from C3 Energy to C3 IoT to reflect its broadened approach to systems solutions for the "Internet of things" (IoT).
- A tour of the facilities at E&J Gallo Winery provided perspective on the scope and scale of the company's operations. Senior management also discussed how the company uses systems approaches to manage multiple product lines, raw goods, and production. A dinner networking event gave students the chance to talk with management in more depth.
- At Google, students explored the company's new technology lab (ACME Lab) and learned first-hand how cutting-edge technologies are investigated and tested.
- The visit to Intel's New Devices Lab enabled students to gain perspective on how a venture into the development of devices can benefit a traditional chip manufacturer. One highlight was a hands-on demonstration of wearable devices.
- At Tesla, students learned about the company's vision for the future of the automotive industry and its approach to autopilot technology. Highlights included a test drive in the new Model X and a preview of the new Model 3.
- Executives at the Visa Innovation Lab described how changing payment practices are accelerating the need for innovation and product development. The group took a tour and gained insight into how collaborative workspaces can accelerate the development of new product concepts as well as discussions with key customers.

E&J Gallo Winery

C3 IoT



Visa Innovation Lab

Tesla Motors

Upcoming Tech Treks

The fall 2016 (Greater Boston) and spring 2017 (Silicon Valley/San Francisco Bay Area) SDM Tech Treks are currently being planned. If your company would like to participate in future SDM Tech Treks, please contact Joan S. Rubin, SDM executive director (interim) and industry codirector, at jsrubin@mit.edu, 617.253.2081, or Jonathan Pratt, director of SDM recruitment and career development, at jonpratt@mit.edu, 617.327.7106.

Snapshot: SDM Cohort Entering in Fall 2016

On August 22, 2016, MIT welcomed a new cohort of 57 early to mid-career technical professionals to the System Design & Management (SDM) program. As in the past, fellows in the newest SDM cohort come from a wide range of industries, among them government, energy, healthcare, software, information technology, consulting, the US military, and more. They work for well-established companies, new industries, and startups. Several SDM '16s are entrepreneurs.

MIT System Design & Management Class Entering in 2016

Tochi Nwachukwu

Program Manager, Microsoft

"At SDM, I will learn how to lead effectively and creatively, using systems thinking to solve large-scale product development challenges. As a distance student, I can apply what I've learned to my work at Microsoft throughout my matriculation."

Gabriella Ricart Surribas

Consultant, Accenture

"As an SDM fellow, I will learn to use systems thinking to strengthen my technical expertise, provide strategic leadership, and drive change more effectively. I will also have opportunities to develop lifelong relationships with brilliant MIT faculty and my peers."

Shelley Chan

Senior Data Analyst, Lyft

"In terms of my experience and career goals, SDM appears to be a perfect fit. I will learn about systems engineering, how it relates to data, and how it can be used across different industries and functions."

Masahiro Yamada

Chief Planner, Central Japan Railway Company

"Because my work involves complex technologies and associated business and sociopolitical challenges, it must be very systematic. SDM's focus on design and management of systems will provide me with skills critical to the success of the superconducting magnetic levitation railway."

Demographics*

- 41 men / 16 women

Sponsorship

- 19 company-sponsored
- 38 self-sponsored

Average age

- 32

Program

- 38 on campus
- 15 local commuter
- 4 distance

Citizenship

- Argentina, Canada, China, Cyprus, France, India, Indonesia, Italy, Japan, Mexico, Nepal, Netherlands, Nigeria, Pakistan, Rwanda, Saudi Arabia, Singapore, Spain, Turkey, United States

Sarah Summers

Flight Test Engineer, US Air Force

"My SDM education will help me expand and deepen my expertise as a US Air Force acquisitions leader who provides military equipment to the warfighter."

George Lordos

Chairman of the Board and Finance Director, GDL Trading Ltd.

"SDM is my first step toward a PhD in strategic engineering. I am interested in a re-envisioning of manufacturing systems that can lead to step-change increases in productivity and efficiency."

Shweta Jindal

Senior Hardware Engineer, Broadcom

"SDM's curriculum, which provides a blend of engineering and management, will enable me to transition into product management and help develop state-of-the-art hardware."

Christian West

CEO, Lightning Kite

"SDM will offer me opportunities to interact with, and learn from, talented, passionate, and intelligent professionals at MIT and contribute to solutions to complex, global challenges that affect individuals worldwide."

Davide Lasi

Project Manager, Space & Planetary Services Division, University of Bern (Switzerland)

"I chose SDM because the success of ambitious space missions depends on leaders capable of mastering both the technical and the management challenges that arise in complex systems development."

Lwin Moe

Software Development Manager, GEICO

"In this age of driverless cars, the Internet of Things, and artificial intelligence, thinking creatively is essential to solving increasingly complex business problems. Systems thinking is a prerequisite to success in these ever-changing business environments, and SDM will prepare me to rise to the challenge."

**Admissions numbers accurate as of press time.*

sdm Conference

2016 MIT SDM Conference to Focus on Reinventing Innovation with Systems Thinking

The annual Conference on Systems Thinking for Contemporary Challenges at MIT, sponsored by the System Design & Management (SDM) program, will be held on September 28, 2016, in Wong Auditorium on the MIT campus. The theme for this year's event is *Reinventing Innovation: A Systems-Based Approach to New Products, New Services, and a New World*.

Joan S. Rubin, SDM executive director (interim), industry codirector, and conference convener, said innovation is a must for integrating the technical, managerial, and socio-political components of large-scale complex challenges. "A whole systems approach can enable a critical competitive edge in quality, time to market, and overall success. The SDM conference and all related events are designed so that attendees can learn how successful, visionary innovators use a whole systems approach, then return to the office with practical ideas for implementation in their own domain."

Conference speakers will include leaders in engineering, management, and entrepreneurship from a wide range of sectors. They include:

- Leandre Adifon, vice president for Enterprise Systems Engineering & Advanced Technology at Ingersoll Rand and a graduate of the SDM Graduate Certificate Program in Systems and Product Development (keynote);
- Donna Levin, co-founder of Care.com and MIT entrepreneur in residence (keynote);
- Bernard S. Meyerson, vice president and chief innovation officer of IBM and an IBM fellow (keynote);
- Olivier L. de Weck, PhD, dipl.-Ing., professor of aeronautics and astronautics and engineering systems at MIT;
- Bryan R. Moser, PhD, lecturer for MIT SDM and president/CEO, Global Product Design; and
- Rajesh Nair, founder and chairman of Degree Controls Inc., visiting scholar at MIT, senior lecturer and director of the Innovation and Entrepreneurship Center at the Asia School of Business, and SDM alumnus.

Leandre Adifon

Donna Levin

Bernard S. Meyerson

On September 27, 2016, SDM will offer optional preconference events. In the afternoon, back-to-the-classroom sessions will be taught by two of SDM's core faculty members, Dr. Bruce Cameron and John Helferich. Following that, SDM will convene a panel, Reinventing Innovation with Systems Thinking, which is free and open to all. Participants will include innovators and entrepreneurs who will discuss how they are applying systems thinking to groundbreaking work in a wide range of domains,

including water quality, manufacturing, cancer, medical informatics, and marketing. The panelists are:

- James A. Barkley, director at UI LABS responsible for Digital Manufacturing Commons at the Digital Manufacturing and Design Innovation Institute and SDM alumnus;
- Susan Conover, lead for an early stage medical technology startup that is developing a tool to identify skin cancer and SDM alumna;
- Christopher Garcia, MD, research fellow in pathology and informatics at Massachusetts General Hospital and SDM alumnus.

> For details on all upcoming SDM events, please visit
>
> sdm.mit.edu

http://

Mark Your Calendar

2016 MIT SDM Conference on Systems Thinking for Contemporary Challenges and Related Events

Please join us on September 27-28, 2016, for the annual MIT SDM Conference on Systems Thinking for Contemporary Challenges and preconference events. This year's focus will be on a systems-based approach to reinventing innovation.

September 27

Preconference back-to-the-classroom sessions 1:30-4:30 p.m., Wong Auditorium, MIT

Panel: How to Scale Your Big Idea in a Complex World: Reinventing Innovation with Systems Thinking
5-6:30 p.m., Wong Auditorium, MIT

September 28

2016 MIT SDM Conference on Systems Thinking for Contemporary Challenges
Reinventing Innovation: A Systems-Based Approach to New Products, News Services, and a New World
8 a.m.-5 p.m., Wong Auditorium, MIT

SDM Information Evening 6-9 p.m., Morss Hall, MIT—Learn about the MIT master's degree in engineering *and* management.

HUBweek 2016

All of the aforementioned events will be part of HUBweek, Boston's annual weeklong celebration of innovation and creativity, which is cosponsored by MIT, Harvard, Massachusetts General Hospital, and *The Boston Globe*. The September 27 panel will help kick off HUBweek's "Innovation in Kendall Square" night.

To learn more about HUBweek offerings from September 25-October 1, 2016, visit **hubweek.org**.

2016 fall sdm calendar

AVAILABLE

> on demand

Virtual SDM Information Session:
sdm.mit.edu/virtual-sdm-information-session/

Prerecorded webinars:
sdm.mit.edu/news-and-events/webinars/

> SDM Pulse online

To read this and past issues of the *SDM Pulse* on the web, visit **sdm.mit.edu/pulse/**

Details for all events are at **sdm.mit.edu**.

2016 MIT SDM Conference on Systems Thinking for Contemporary Challenges and Related Events

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September 27–28, 2016

For details, please see page 27 or visit **sdm.mit.edu** for further details and registration.

Grace Hopper Celebration of Women in Computing

October 19-21, 2016

MIT SDM will be exhibiting at this event in Houston, TX. Please stop by!

MIT SDM Systems Thinking Webinar Series

This series features research conducted by members of the SDM community.

Except where noted, all webinars are held on Mondays from noon to 1 p.m. and are free and open to all. For details, registration, and access to recordings and slides from prior webinars, visit **sdm.mit.edu/news-and-events/webinars/.**

September 12, 2016

Building an AI Product to Improve High-Tech Sales
Bryan Pirtle, cofounder, Nova.ai; SDM fellow

October 17, 2016

Agile Project Dynamics: A Strategic Project Management Approach Using Systems Dynamics for Large-Scale Software Development
Firas Glaiel, corporate technology area director, Raytheon; SDM alumnus

October 31, 2016

Overengineering in Systems Design
Christine Miyachi, systems engineer and architect, Xerox Corporation; SDM alumna

November 14, 2016

A Systems-based Approach to Improving Last Mile Logistics
Ali Kamil, cofounder and director of product, Wise Systems; SDM alumnus

November 28, 2016

Model Use in Sustainability Negotiations and Decisions
Ellen Czaika, PhD, Climate Corps fellow, Environmental Defense Fund; SDM alumna

Massachusetts Institute of Technology

Event listings contain all details available at press time. Final information is available at **sdm.mit.edu** two weeks prior to each event.