vol. 12, no. 1 | spring 2017

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

sdm pulse

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Massachusetts Institute of Technology

Tech Trek Report

Photo Courtesy of Bose Corporation © 2016

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sdmpulse

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MIT System Design & Management is jointly offered by the MIT School of Engineering and the MIT Sloan School of Management.

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

On the cover: SDM students had the opportunity to test a prototype of the Bose Ride (pictured) during a fall 2016 tech trek visit to the Bose Corporation's campus in Framingham, MA. The Bose Ride is a seat suspension system, a seat suspension system for heavy trucking that reduces driver fatigue. (See article on page 26.)

MITsdm

Welcome

As many of you may already know, Pat Hale recently retired as SDM executive director. Pat joined SDM in 2004, and thanks to him the program has flourished. On page 24 you will find a tribute to Pat highlighting his contributions to SDM and the field of systems thinking. We wish him the best!

I would also like to let you know that I have been appointed SDM executive director and senior lecturer. The article on the facing page provides details.

I look forward to working with all of you in this capacity!

This issue of the *SDM Pulse* features several excellent articles by SDM alumni and faculty. Together they demonstrate a wide spectrum of systems thinking applications. For example:

- how to design a transmission for a new hybrid supercar;
- why your workforce might resist adopting 3D printing and how you might tackle this challenge;
- a new paradigm for improving healthcare and increasing employment opportunities by offering affordable medical devices across Africa;
- a look at product design for social impact—aiding smallholder farmers in Thailand; and
- a model for sustainability negotiations among various stakeholders that can be applied in a wide range of scenarios.

In addition, you will find a series of articles reporting on recent and upcoming activities that describe ways you and your company can get involved with SDM. This includes:

- a fall 2016 tech trek report on visits to Bose and Shell TechWorks;
- a sneak peak at the companies SDM students will visit on the spring 2017 tech trek to Silicon Valley;
- information on SDM's upcoming live and virtual info sessions and webinars.

You will also find a feature on the latest winner of the MIT SDM Student Award for Leadership, Innovation, and Systems Thinking.

We hope you enjoy this issue and welcome your feedback and suggestions.

Sincerely,

Joan S. Rubin
Executive Director and Senior Lecturer
MIT System Design & Management
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Joan S. Rubin Appointed MIT SDM Executive Director and Senior Lecturer

By Lois Slavin, SDM Communications Director

Joan S. Rubin has been named executive director and senior lecturer of the Massachusetts Institute of Technology's System Design & Management (SDM) program.

As executive director, Rubin will be responsible for managing all facets of SDM to support the vision of a technically grounded degree program that develops leaders who can manage complex systems in an ever-changing world. Rubin will work closely with SDM's faculty codirectors to review SDM's vision and will then develop a three-year strategic plan that establishes the program's top priorities for students, alumni, faculty, and corporate partners.

Rubin will also work directly with SDM students, advising them on their academic paths and careers beyond MIT. In addition, she will oversee the creation of new offerings for SDM alumni interested in career and professional development.

In her senior lecturer role, Rubin will work with SDM faculty to continue to evolve the core courses, engage faculty from across MIT in the SDM program, advise and supervise SDM fellows on thesis research, guide certificate students on group capstone projects; and teach.

Rubin joined SDM in 2010 as industry codirector and was instrumental in increasing the engagement of existing SDM industry partners and recruiting new ones. Among other important accomplishments, she was influential in redesigning the SDM core course sequence; she restructured the admissions process to improve the quality of admitted students; and she has broadly expanded SDM's outreach and involvement with the corporate community.

Prior to joining SDM, she served as vice president of Covidien, a leading manufacturer of medical devices and supplies. As a graduate of MIT Leaders for Global Operations, Rubin holds an SM in management and an SM in mechanical engineering. She also earned an ScB in mechanical engineering from Brown University.

About the Author

Chad Jacoby is a captain in the US Coast Guard where he serves as the assistant program executive officer for command, control, communication, computers, intelligence, surveillance and reconnaissance (C4ISR) systems. He is a professional engineer and certified acquisition program manager. He holds a BS in civil engineering from the US Coast Guard Academy, an MEng in mechanical engineering from Old Dominion University, and, as an SDM alumnus, a master's degree in engineering and management from MIT.

Employing Systems Thinking to Reduce Emissions While Increasing Supercar Performance

The challenge: The human brain is wired to solve problems by drawing on the past and improving on what we already know. Often, it is difficult to erase our understanding of what things "should look like" and design a solution that flows from required system functions instead of pre-existing mental models. Systems engineering, system architecture, and innovative problem-solving techniques provide tools to remove artificial limitations and open up new design possibilities.

In 2014, a leading maker of high-performance vehicles (supercars) challenged a group of MIT graduate students with a seemingly impossible task: Design a transmission for their new hybrid supercar that:

- adds an electric motor,
- retains blistering performance, and
- is smaller and lighter than before the electric motor was added.

This paradoxical challenge pulled me in, frustrated me, then gave me a chance to practice systems thinking and accomplish something I could not have envisioned at the start of the project.

The approach: Because my first two degrees are in civil and mechanical engineering, my initial, almost preprogrammed reaction to the challenge was to think of it as an optimization problem. I asked, "How do I squeeze enough efficiency out of each of the transmission components to make room for the electric motor?" This approach proved difficult. World-class mechanical engineers have spent more than a century refining the manual transmission's design by removing weight and reducing the size of each component. Even if I could implement multiple incremental innovations, they would probably only add up to a couple pounds and a couple inches—not enough to make room for an electric motor capable of launching a supercar. ("Launching" means accelerating very rapidly from a dead stop.) Yet, I dreaded the idea of having to tell the car company that I could not figure out a way to meet their challenge.

While I was struggling to improve an already well-refined mechanical design, I was taking MIT System Design & Management (SDM) classes that focused on systems engineering, system architecture, and radical innovation. The tools from these SDM classes allowed me to look at the challenge from a different perspective than those from my mechanical engineering days—a systems perspective. I decided to throw away everything I knew about what automotive transmissions are "supposed to look like" and start with a blank piece of paper to define the functions that a hybrid automotive powertrain must fulfill.

The tools: Object process modeling (OPM) and the TRIZ problem-solving method provide system engineers with techniques to explore the design space holistically, creatively, and systematically. Leveraging OPM, I documented the hybrid automobile system functions, including:

- accelerating,
- charging,
- starting the internal combustion engine (ICE)
- braking,
- gear shifting, and
- reversing.

TRIZ enables thinking by analogy. It is a simple but powerful way to relate a specific problem to an abstract problem, apply an abstract solution, then convert the abstract solution back into a specific solution for your problem. The TRIZ Principle of Universality asks the question, “Can two or more goals be achieved by the same structure?” Based on the required system functions mapped using OPM and the TRIZ Principle of Universality, I allocated the required hybrid-electric transmission functions to the lowest possible number of form elements, for example: electric motors, internal combustion engine, forward gears, and friction brakes.

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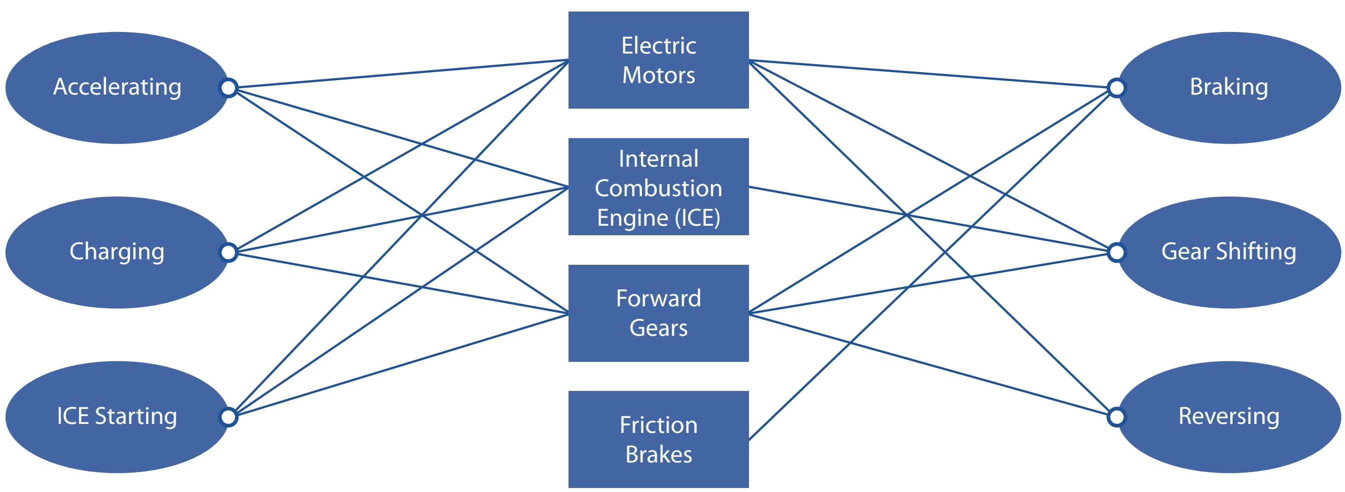

Figure 1. Object process modeling was used to map function to form in addressing the supercar challenge.

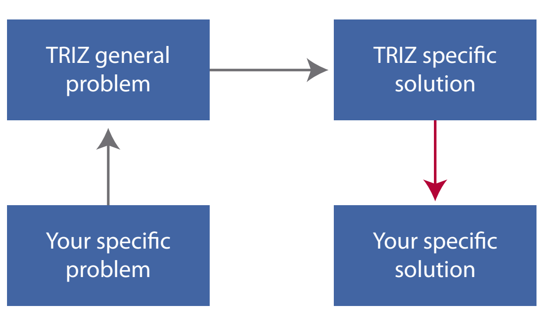

Figure 2. The TRIZ problem-solving method relates a specific problem to an abstract problem, applies an abstract solution, then converts the abstract solution back into a specific solution. This method proved useful in designing a new transmission for a hybrid supercar.

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After multiple iterations, I found that all of the required system functions could be accomplished by a relatively small number of transmission components. This analysis suggested that a transmission could be designed to meet all of the functional requirements of a hybrid supercar without some of the form elements that are traditionally used. Specifically, once electric motors are integrated into the design, there is no need for reverse gears or a friction clutch.

The results: Manual transmissions are efficient because they are simple. For example:

- they do not have a lot of extra spinning mass to leach engine power;
- they have simple pairs of internal gears that can be engaged to select differing gear ratios; and
- once a pair of internal transmission gears are engaged, they provide a direct line to transfer power from the power source to the wheels.

A key design criterion for a manual supercar transmission is the ability to shift between the gears quickly. If two gears are spinning at different speeds and the driver attempts to mesh them together (by shifting into first gear, for example), the gears will "grind," and the gear teeth will be damaged. For a manual transmission to shift smoothly, there must be a way to speed-match gear sets so they can be engaged without damage. The traditional approach to this problem is to use a friction clutch, which allows the gear running at higher revolutions per minute (RPM) to slow down to match the speed of the lower RPM gear before engagement.

This design has two substantial drawbacks:

- it requires a large clutch mechanism that adds size, weight, and rotating mass to the transmission; and
- it results in a loss of acceleration, or shift lag, while gear RPMs are slowed prior to engagement.

By embedding electric motors upstream and downstream of the transmission gear sets, my design allows the car's electronic control unit (ECU) to fully control the RPMs at any given gear set in the transmission.

This provides the following advantages:

- instead of slowing the higher RPM gear to speed-match a gear set, the electric motor can speed up the lower RPM gear to allow the gear set to engage without damage;
- utilizing the electric motors for acceleration, deceleration, and gear shifting obviates the need for a friction clutch;
- since the ECU is also capable of reversing the rotation of the electric motors, the transmission no longer needs a reverse gear and its associated shafting; and
- as a result, it is possible to remove the double wet clutch, the clutch oil reservoir, the reverse gear shaft, and the associated transmission housing—making room for more than 100 pounds of electric motors and supporting equipment.

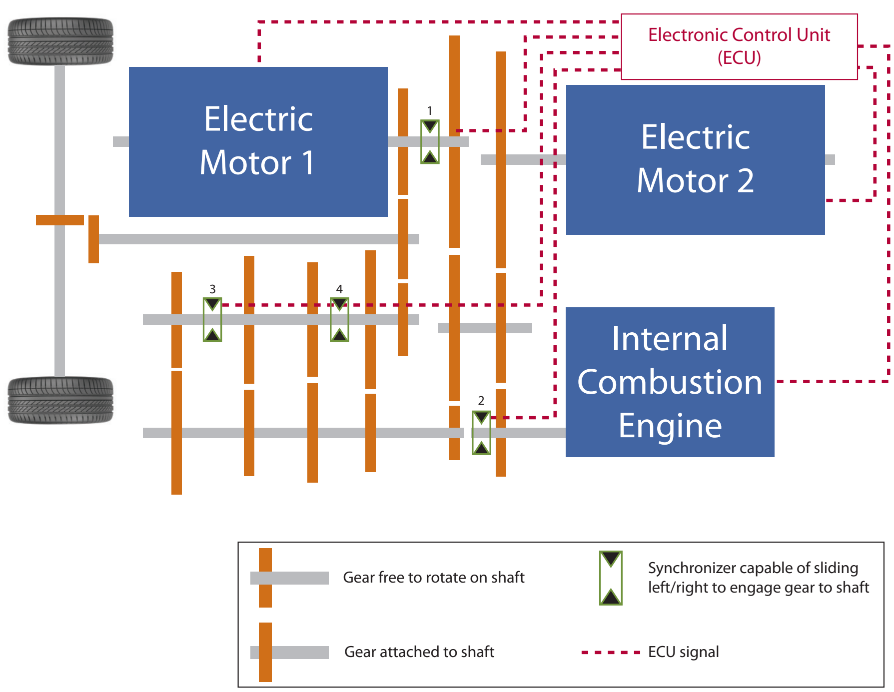


Figure 3. The conceptual transmission gear arrangement developed for the hybrid supercar utilizes two electric motors and an internal combustion engine to accomplish the system's functional requirements.

The resulting arrangement enables the hybrid supercar to operate in:

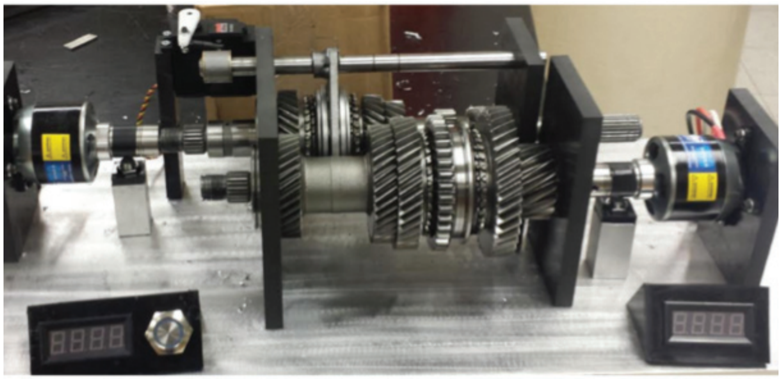
- electric mode (zero-emission driving using electric motors and batteries),
- launch mode (rapid acceleration from a dead stop using electric motors and the ICE),
- drive and charge mode (electric mode while charging the batteries using the ICE),
- park and charge mode (charging the batteries with the ICE while stationary),
- regular driving mode (eight forward gears utilizing electric motors and ICE),
- reverse mode (zero-emission backing using the electric motors and batteries), and
- ICE starting mode (using the electric motors to start the ICE).

The application of system design tools allowed me to meet the challenge laid out by the supercar company, to:

- reduce emissions,
- maintain supercar performance,
- integrate an electric motor, and
- make the transmission lighter and smaller.

In fact, harnessing the electric motor's explosive low-end torque, engaging the internal combustion engine at the optimal point on its power curve, and eliminating shift lag will significantly improve the supercar's 0-60 mph acceleration time.

I built a prototype of the design using the gear sets from a small manual transmission, brushless electric motors, a large servo to shift the synchronizer, and a laptop to serve as the ECU. I traveled to Europe in 2015 with the prototype to pitch the design to car company engineers and executives with very positive results.



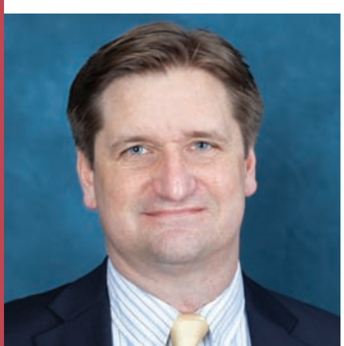
This clutchless shifting prototype was built to demonstrate the feasibility of speed matching gear sets using brushless motors.

Next steps: A provisional patent was filed in 2015, and an international patent application was filed in 2016 for Clutchless Shifting of a Manual Transmission. The MIT Technology Licensing Office is currently pursuing potential licensing opportunities. The design is also the basis for follow-on work in the MIT Department of Mechanical Engineering where a PhD student is developing additional capabilities based on the clutchless shifting concept. Many advances in automotive technology started in the high-performance sector then were later applied to general automotive designs. Application of this design for reduced emissions in passenger cars would be much easier due to the less stringent acceleration and top-speed requirements of such cars.

This project gave me an opportunity to look at a problem from a systems perspective, employ tools from the SDM curriculum, and come to a solution that I initially could not see. I am excited to continue with the project and look forward to driving a clutchless hybrid supercar!

About the Authors

Shawn H. Chang is a graduate of MIT System Design & Management (SDM), where he was a Mitsubishi Heavy Industries Fellow and a teaching assistant for SDM's core engineering class. Prior to MIT, he spent 10 years in the advanced materials, technology consulting, and financial services industries. Chang has an MBA from Boston University's Questrom School of Business and a BS in aerospace engineering from Embry-Riddle Aeronautical University.



Dr. Bryan R. Moser is an MIT SDM lecturer and a project associate professor at the University of Tokyo focused on the study and design of socio-technical systems. His work integrates 25 years of industry experience and fieldwork with new research, including observation of teamwork, interactive visualization, behavior-based simulation, and cross-functional workshops for complex, real-world missions. His industrial experience includes technology development, rollout, and sustainable operations in aerospace, automotive, heavy machinery, transportation, energy, telecom, and global services.

Addressing Socio-technical Barriers to Adopting 3D Printing Technology

The challenge: The first steps in adopting 3D printing (3DP) can be challenging because manufacturers have traditionally relied on decades of know-how, and often success, to produce large portfolios of parts. Employees faced with the new method can be overzealous or overly cautious, and often they do not understand the technology, the software, and the materials specific to 3DP—which can put the effort at risk, if 3DP is attempted at all.

Inspired by an SDM core team project sponsored by Mitsubishi Heavy Industries, we set out to identify variables that complicate or impair judgment when manufacturers consider adopting 3DP.

The approach: We proposed using a systematic approach to analyze the relative value of 3DP for prototyping and producing parts and products. The outcome is a framework that combines part-level feasibility with the systemic benefits of cost and schedule improvements. Both prototyping and production alternatives were considered.

In building this framework and in interviews with experienced manufacturers, we confirmed two key insights:

- Considering the feasibility of adopting 3DP part by part is daunting, because this process often requires a huge investment of time, money, and know-how.
- Adopting 3DP requires technical and social readiness—i.e., an openness to the concept of applying 3DP technology as well as a willingness among people in receiving systems and organizations to implement it.

By viewing 3DP insertion as a socio-technical system that is implementing the changes, attention can be drawn to the tacit knowledge of critical characteristics in existing manufacturing processes, design-for-manufacturing decisions embedded in existing part assemblies, the preprocessing and post-processing capabilities available to shift 3DP feasibilities, and the alignment of organizational learning across parts.

Studies of 3DP feasibility have focused primarily on technology readiness, parts value (cost and time), and process planning (timing, externalities, etc.). Our research examines the socio-technical dynamics (i.e., people, their experience, and their habits of thinking) that affect the technology adoption cycle, from which we investigate the attributes that contribute to the design, prototyping, tooling, and production of parts. Our objective is to expose the technology adoption risks and benefits at both a local (part) and systematic (product organization) scale as they influence product development choices.

Several interviews with manufacturing process experts pointed to adoption barriers beyond value analysis. These industry experts emphasized that the cost, quality, and schedule of a manufactured part in many cases is the result not simply of an automated process, but of a combination of technology, process, and the tacit knowledge that aligns the materials, the designs, and the manufacturing environment. Therefore, an existing part, as designed and as manufactured, embeds a legacy of previous choices into the part itself, and also into the preprocessing, material choices, the manufacturing environment, the role of quality during production, post-processing, and verification and validation.

This history of choices as background knowledge is both tacit and explicit. Even if a traditional manufacturing technology (e.g., machining) is replaced by 3DP, the remaining elements in the total engineering and manufacturing process might still be aligned with the previous process. Early failures due to such misalignment may in turn lead to an adoption-averse organization.

For many companies, current production techniques are backed by years of know-how that have led to high-quality, reliable parts and/or systems. Know-how for new engineering and production methods takes time to develop, leading us to ask:

> *How can one adopt new 3DP product development and production methods at an optimized pace while minimizing the risk of poor quality and loss of know-how?*

Recognizing this key question, the approach to 3DP adoption should support existing product and process experts in the field so they can:

- more rapidly evaluate and prioritize the potential application of additive manufacturing to a specific product system;
- more rapidly capture lessons learned and insights from this evaluative process—linked (tagged) to product characteristics, process, and additive manufacturing options; and
- more efficiently share adoption rules and insights across product systems and business units.

The tools: The framework begins with filtering the bill of materials (BOM) or parts list for both insourced and outsourced parts. Outsourced parts were not considered, but insourced parts undergo a further filter to classify parts as intended either for prototypes or for manufacturing.

The respective part attributes for prototype and manufacture intents are mapped against the 3DP technology, both tools and materials, for feasibility analysis. Attributes that affect prototyping and production of parts can include:

- complexity of the part geometry and topology, dimensions, and tolerances (dimensional and physical properties);
- material type and diversity;
- intended use and environment;
- appearance (surface finish and aesthetics); and
- strength, certifications, and other relevant elements.

In prototyping, concept validation is often the focus. Rapid prototyping techniques typically help reduce the product development cycle (time and cost). However, this does not necessarily translate to manufacturability as the tools used in prototyping are sometimes not employed in production. This anomaly can lead to well-known risks in manufacturability and feasibility. Manufacturability addresses whether a part can be made to production-intent specifications, and feasibility considers the time and cost, which includes sustainability and yield rate.

As shown in Figure 1, our analysis compares the dimensional/geometric, accuracy/tolerance, material composition, mechanical properties, and quality dimensions of the part and the selected 3DP technology to learn what attributes are within and outside the limits for the part (p) and 3DP technology (T). The feasibility analysis, F(p,T), relies upon part, tool, and material attributes.

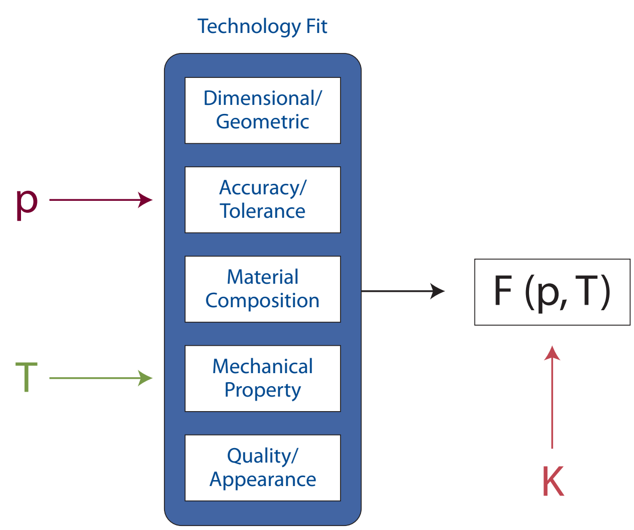


Figure 1. The technology fit, or suitability of a part for 3D printing, is determined by analyzing the part's engineering specifications and requirements and comparing those to the technology and material required for 3D manufacturing.

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Some combination of attributes, for example the part dimensions and machine capabilities, may quickly filter out the part for consideration for 3DP. However, some combinations that appear not quite feasible may yet be compensated for by background knowledge (K). Rather than simply a yes/no filtration, the analysis exposes the basis of feasibility, including risks, with an emphasis on uncertainties to decrease and/or readiness to increase across the p, T, K set.

One aspect emphasized in the feasibility analysis F(p,T) is the importance of considering background knowledge (K, see Figure 2), because such knowledge may indicate which parts are feasible under current 3DP technology (T), and tacit know-how, such as post-processing capability. Inclusion of background knowledge (K) also encourages exploration of the systemic value of the assessed 3DP part, compared to those of a conventionally manufactured, or baseline part.

Taken together, a more detailed view of the method is shown in Figure 2. As the large set of total BOM parts is filtered and prioritized, experts can review, comment, and in some cases adjust the analysis. At

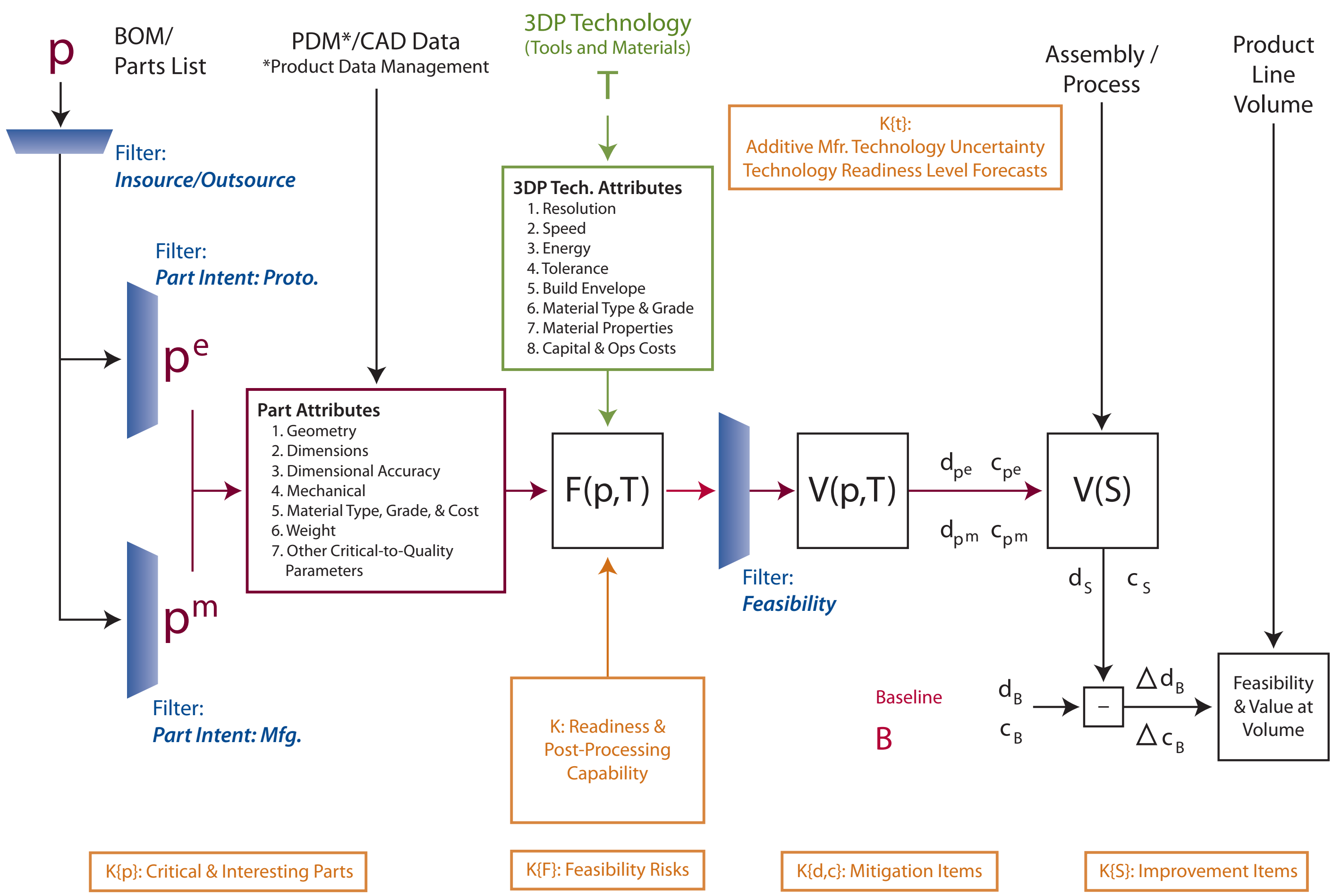

Figure 2. This framework integrating parts, 3DP tools and materials, and process knowledge illustrates how a company's choice of parts for 3DP application emerges from the interplay of both technical and social readiness.

first, with few parts and product systems reviewed, the method will be helpful but still limited to the source knowledge on 3DP technology provided. However, as more and more parts across a portfolio of product systems and 3DP tools and materials are analyzed, similar parts, technology, and issues (p,T,K) will be linked across the organization. In particular, as new 3DP tools and materials emerge, this structured knowledge approach can allow adoption to be considered at an accelerated rate across the most closely related parts of the organization.

The results: This method's emphasis on examining 3DP insertion with a "human in the loop" approach recognizes that tacit knowledge of baseline processes, embedded from years if not decades of organization experience, need to be stimulated to expose relevance (or irrelevance) of the firm's accepted wisdom to the new process. Engaging existing product and process experts helps generate explicit knowledge—in a form that can be shared, tested, and questioned across teams. Indeed, this social process may be essential to enabling the thoughtful and complete assessment of 3DP that will displace historically proven processes in quality, cost, and schedule. The awareness and willingness of human teams to expose and unlearn past assumptions was seen as a significant barrier to early efforts to adopt 3DP.

Shawn H. Chang, left, and Dr. Bryan R. Moser attend the 2016 Annual International Solid Freeform Symposium in Austin, TX. The symposium featured their work on socio-technical barriers to adopting 3D printing technology.

This framework offers a first step by filtering candidate parts and subsystems with an up-to-date combination of the latest material and 3DP tools, and it can stimulate a team-of-teams dialogue more quickly and efficiently. Active engagement of cross-functional experts can accelerate their situational awareness of the feasibility and value of 3DP to the system as a whole, in contrast to taking a piecemeal approach.

This framework was delivered to the sponsor for internal application and published at the 2016 Annual International Solid Freeform Symposium in Austin, TX. Preparation for demonstration as well as application to other technology insertion challenges is under way.

About the Author

Oluwasoga Oni is CEO of MDaaS, a medical services startup based in Nigeria that provides flexible acquisition options and service support for Nigerian hospitals. Previously, Oni worked as a software engineer for a large multinational data storage organization. He holds a bachelor's degree in information and communication technology from Covenant University in Ogun, Nigeria, a master's degree in electrical engineering from the Illinois Institute of Technology, and, as an SDM graduate, a master's degree in engineering and management from MIT.

Improving Healthcare and Increasing Employment Opportunities by Offering Affordable Medical Devices Across Africa

The challenge: Medical devices have the power to transform the healthcare landscape and dramatically improve health outcomes around the globe. However, access to life-saving medical equipment and supplies is far from universal. Nigeria, for example, does not have enough medical devices to serve its 180 million people. According to the World Health Organization, 40 percent of the medical devices in Nigeria are currently out of service. In many parts of the country, this dearth of functioning medical equipment means that diseases are diagnosed too late or not at all.

Various stakeholders (such as manufacturers, government agencies, and nongovernmental organizations) are now tackling this equipment imbalance by:

- donating equipment;
- building low-cost devices with reduced functionality; and
- subsidizing equipment costs.

However, these approaches have had only limited impact over both the short and long terms because:

- most donated equipment ends up broken within the first year;
- design and manufacturing of new kinds of devices for developing countries takes years and doesn't scale across all types of equipment; and
- subsidizing equipment is not economically sustainable over the long haul.

These challenges are exacerbated by the fact that 60 percent of the healthcare services in Nigeria are delivered by private health facilities, while most medical equipment interventions occur in both public and nonprofit sectors. The equipment gap is therefore most acute in the private sector.

The approach: Medical Devices as a Service (MDaaS) is developing a formalized secondary equipment marketplace for high-quality medical equipment in Nigeria and across Africa. This marketplace is designed to provide refurbished, full-featured medical equipment at price points that private healthcare facilities can afford. The company offers several different acquisition options, including direct purchase, equipment rental, and leasing.

To equip this marketplace, MDaaS is currently sourcing from independent medical equipment dealers in the United States, where thousands of lightly used devices lie idle in warehouses. MDaaS refurbishes this equipment for the African market, and in so doing, supplies name-brand, high-quality medical devices for as little as 20 percent of the cost of the latest model.

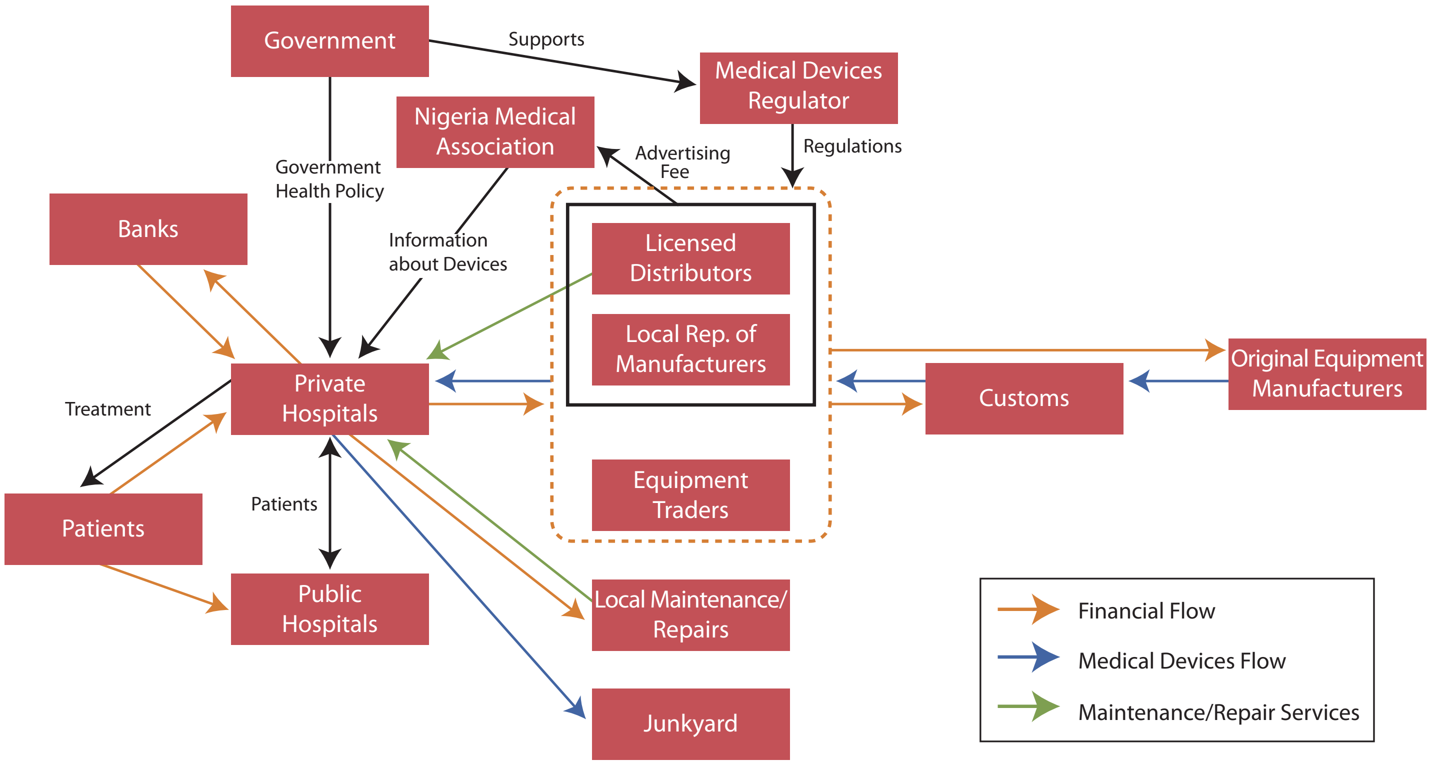

Figure 1. MDaaS mapped out the most critical stakeholders in Nigeria's medical devices marketplace to develop this chart of stakeholders in the nation's private hospital medical device supply chain.

In the near future, MDaaS plans to extend its equipment sourcing both globally and locally, thereby building its capacity to refurbish equipment in every country in which the company operates. MDaaS also supplies experienced biomedical engineers to train local technicians, thereby helping to narrow the skills gap and create jobs.

The tools: MDaaS' approach to solving Nigeria's medical device challenges was developed using interactive planning from the Idealized Design Framework pioneered by organizational theorist Russell Ackoff. Interactive planning entails analyzing the existing system's current status, projecting an ideal system, and then planning backward from where one wants to be to determine how to reach that ideal.

Interactive planning involves a two-part process comprised of six major steps:

Idealization:

- formulating the mess, and
- ends planning.

Realization:

- means planning,
- resource planning,
- design of implementation, and
- design of control.

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Here is an outline of how MDaaS navigated these six steps to address Nigeria's medical equipment challenge.

Formulating the mess

We used the stakeholder value network to map out and determine the most critical stakeholders in Nigeria's medical devices marketplace, then interviewed them. They included:

- doctors,
- original equipment manufacturers,
- device distributors,
- government officials,
- banks, and
- patients.

Formulating the mess helped us identify several underlying factors behind the emergent system state (inaccessibility of medical devices):

- the expense of high-quality equipment;
- little incentive for doctors to invest in high-quality equipment for low-income patients;
- substandard alternatives (equipment that is cheap and unsuited to the harsh tropical climate often breaks down);
- few or nonexistent financing options for medical devices;
- a shortage of skilled biomedical technicians that leads to broken equipment remaining broken; and
- a highly fragmented marketplace.

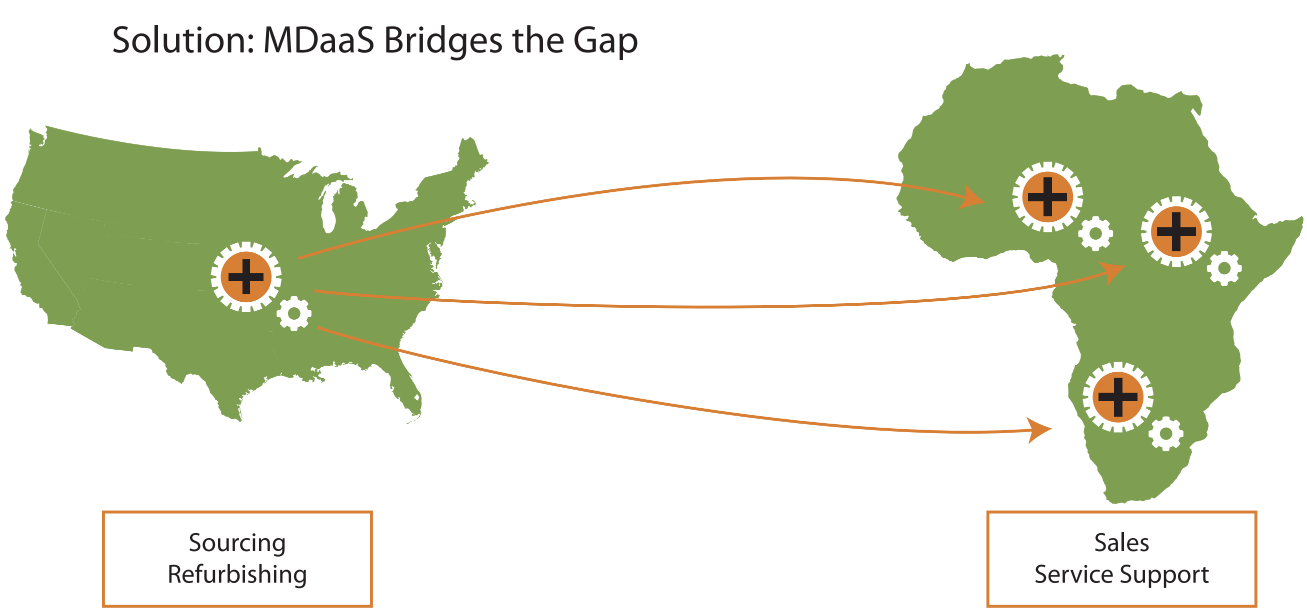

Figure 2. MDaaS' business model, illustrated above, is based on sourcing used medical equipment from the United States and refurbishing it for the African market.

End planning

During this process, we imagined what a perfect medical equipment marketplace would look like if we could design it from scratch. The only limitations we gave ourselves were that whatever we designed needed to be technically feasible and able to exist within Nigeria's system of laws and regulations. Under these assumptions, we determined that an ideal medical equipment market would have the following characteristics:

- equipment prices suitable for hospitals serving low-income patients who are unable to pay premium prices;
- financing options for equipment purchase;
- options for equipment acquisition, such as leasing, renting, and pay-per-use;
- inventory that included a variety of medical devices and an ample supply of spare parts;
- enough skilled biomedical technicians in the country to maintain and service all devices in Nigeria on a timely basis;
- equipment uptimes of over 99 percent; and
- equipment training for clinicians and technicians.

Means planning

During this stage, we attempted to bridge the gap between the current equipment marketplace and our ideal. We identified key components for our business model by answering the following questions:

Can we get high-quality medical devices at a significant discount and have a decent margin?
Yes! After studying the US and EU medical devices industry, we discovered that the secondary marketplace offers significant value for medical devices, especially since new equipment depreciates rapidly. We are building a network of suppliers in the United States that gives us access to an inventory of used and refurbished devices at very competitive prices.

Can we provide financing options to our clients?
We found that the capital and risk implications of offering financing directly to clients would be too much for a small startup like MDaaS to bear. Therefore, we decided to partner with existing financial institutions to offer financing. We plan to reduce their exposure in the marketplace by offering technical support and buy-back guarantees.

How can we provide world-class service support for each device?
Because this will require a significant amount of training, we are investing heavily in hiring and training biomedical technicians.

Who is the target customer?
Our target customers are about 9,000 private healthcare facilities across Nigeria that have large patient volumes.

What equipment are we supplying?
We are focusing on the most popular devices in radiology, patient monitoring, and critical care, such as X-ray and ultrasound machines, patient monitors, defibrillators, and ventilators.

Resource planning

Once we knew what kind of organization we wanted to build, we estimated all the resources (personnel, capital, and goods) needed to launch a pilot to test our assumptions. We then proceeded to raise capital through grants and equity investment.

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Design of implementation

We planned our pilot with three hospitals in three different cities in Nigeria. We assigned roles within our team and created a schedule for the pilot. We also found equipment suppliers and scouted for other potential partners.

Design of control

Finally, we determined metrics for measuring impact beyond the usual key performance indicators used in business. We will track our success by evaluating the following factors:

- number of health facilities we serve;
- number of pieces of equipment in the field;
- equipment uptimes;
- number of medical procedures performed with MDaaS-supplied devices;
- amount of time needed to service equipment after a breakdown; and
- number of devices per population.

The results: Using Ackoff's Idealized Design Framework changed the company's approach to tackling the medical devices problem in Nigeria and led us to our central thesis: Many devices needed in Nigeria (and Africa) already exist, but are lying idle in warehouses around the globe. The actual challenge, however, involves not only finding the right product fit, but also refurbishing and distributing equipment at affordable prices, as well as providing and training skilled resources for long-term service support.

Since MDaaS officially launched in January 2015, it has generated more than $100,000 in revenue, employed five staff members, and supplied 15 pieces of equipment across five hospitals in three different Nigerian cities. This MDaaS-supplied equipment has been used in more than 2,000 procedures—and counting.

Next steps: MDaaS is now considering three major routes to growth:

- *Scaling into other African countries.* Many hospitals in Africa have the same medical equipment challenges as Nigeria. Since launch, MDaaS has fielded equipment request from Ghana, Kenya, Uganda, and Ethiopia. Expanding into these countries is one of the ways MDaaS will grow. Our priority will be countries with large private health sectors.
- *Offering more services.* We are considering establishing flagship diagnostic centers to offer radiology services directly to patients.
- *Expanding inventory.* The focus at MDaaS is currently on basic radiology devices such as X-ray, ultrasound, patient and fetal monitoring, as well as critical-care devices. We plan to expand this portfolio to include radiotherapy devices and advanced radiology, such as computerized tomography scan and magnetic resonance Imaging machines.

About the Author

Aukrit Unahalekhaka is the cofounder of Ricult, a financial technology startup that uses data analytics to provide high-quality farm inputs to farmers on credit at affordable rates. Ricult has won the MIT IDEAS Global Challenge, the MIT-China Innovation Prize, and was selected as one of 16 top startups from across MIT to join the MIT Delta V Accelerator. Unahalekhaka received a master's degree in engineering and management from MIT as a graduate of System Design & Management. He was also a Legatum Fellow and completed the Sloan Sustainability Certificate. Prior to MIT, he was a consultant at Accenture and a software engineer at Cisco. He holds a BS in computer science from the University of Illinois and an MEng in operations research from Cornell University.

Product Design for Social Impact: A Systems Approach to Aiding Smallholder Farmers

"If you care about the poorest, you care about agriculture. Investments in agriculture are the best weapons against hunger and poverty, and they have made life better for billions of people." —Bill Gates

The challenge: Smallholder farmers are among the poorest and most food-insecure people on the planet. An estimated 1.5 billion to 2 billion people worldwide are dependent on smallholder agriculture, and these smallholders include half the world's undernourished people. In addition, many such farmers live in remote communities with minimal transportation options, communications infrastructure, or access to basic financial services.

Nevertheless, this population provides critical services. One-third of humanity is fed by an estimated 500 million farms with less than two hectares of land. Smallholder farmers are on the front lines of every developing country's food supply. In Asia and sub-Saharan Africa, small farms produce about 80 percent of the food consumed. At the same time, agriculture is a primary source of income and employment in the developing world.

The UN Food and Agriculture Organization has estimated that by 2050, the world will need to produce at least 50 percent more food to feed the projected population of 9 billion people. Failure to meet this demand will result in food shortages and poorer health outcomes for the citizens of developing countries, with damaging consequences for development and the potential for conflict within and between nations.

One challenge to meeting this increased demand is that smallholder farmers face a range of roadblocks in managing their farms as businesses—from purchasing inputs, to accessing financial services, to storing and selling produce. The generations-old techniques and equipment employed by such farmers are relatively inefficient and often produce low yields. Rural families living off the sale of cash crops typically have few savings, and those can be wiped out by a single bad harvest.

In essence, the highly complex and fragmented smallholder agricultural system faces three main issues:

- *Supply chain inefficiencies:* Lack of direct access to consumer markets distorts the prices of both inputs (seeds, fertilizer, etc.) and outputs (food). Poor roads and lack of infrastructure, long distances to towns, and high transportation costs prevent farmers from buying affordable farm inputs and selling their harvest at profit. Consequently, smallholder farmers are often at the mercy of middlemen, who add to the cost and margin at every handoff while transport and storage costs also add up.

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- *Financial exclusion:* Due to lack of credit and difficulty in getting land titles, smallholder farmers face difficulties in accessing the capital needed to run their farms. Traditional banks consider them risky, leaving them at the mercy of other lenders, who can charge 100 percent to 200 percent interest.
- *Information asymmetry:* Because most farmers live in remote areas with limited access to technology, they have no way to obtain critical, time-sensitive data, such as weather forecasts, market prices, farming technique updates, etc. This information asymmetry results in an aversion to risk, low productivity, minimal bargaining power, and very small profits.

Because the problems outlined above are synergistic, they reinforce the vicious cycle of poverty and food insecurity that prevents individuals from living stable, healthy, self-actualizing lives. Unless we change how smallholder farmers grow their food, food security will be at risk, and farmers will remain forever in this unrelenting cycle of poverty. It is clear that something has to be done to address this challenge.

The approach and tools: Growing up in Thailand in a family of farmers, I witnessed these problems firsthand. This led me to launch Ricult, a business whose mission is to give smallholder farmers the tools they need to control their destiny.

Designing products for smallholder farmers at the bottom of the socioeconomic pyramid is different from designing products for users in the developed world because such farmers have different constraints. I began with a holistic, systems-level approach to the problems, then zeroed in on specific details. I have outlined my steps on the following pages.

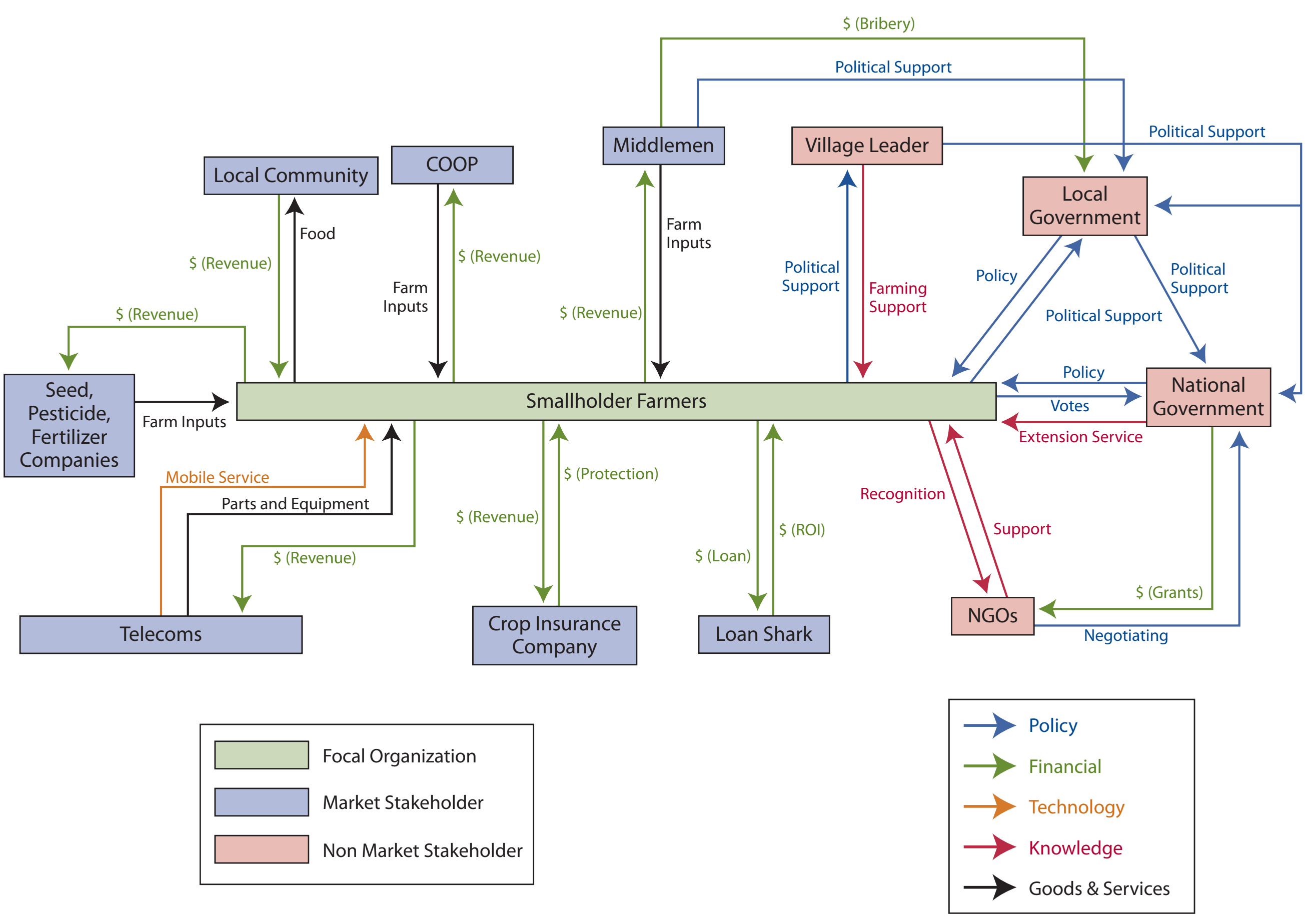

Figure 1. Ricult developed this stakeholder value network (SVN) to show the agricultural value chain common in most developing countries. The SVN helped the company understand its stakeholders, their relationships with one another, and their role in the product's life cycle.

Stakeholder identification and analysis: Research has shown that products often fail because the design team does not have a comprehensive understanding of all pertinent stakeholders' needs, conflicts, and requirements. This failure can be mitigated through the use of the stakeholder value network (SVN) tool as the first step in the product definition phase (see Figure 1).

These smallholder farmers in Kasur, Pakistan, were among the participants in Ricult's first pilot.

Using SVN, I explored the tangible and intangible value exchanges between the population of smallholder farmers and its stakeholders. SVN allowed me to understand pertinent stakeholders, their relationships with one another, and their role in the product's life cycle. Because the poor comprise the majority of the citizens in developing countries, government stakeholders are involved in the system at all levels. Moreover, not all stakeholders have each other's best interests in mind. For example, the middlemen who are exploiting farmers often bribe local government employees to look the other way rather than to enforce farmer protections. These features of the system are critical pieces of the puzzle to consider when designing new, innovative products for smallholder farmers.

Lastly, it is crucial to get support from key stakeholders across the agricultural value chain. There is a clear need for close cooperation among mobile network operators, governments, nongovernmental organizations, and the private sector in order to successfully deliver products, services, and potential benefits to smallholder farmers.

Interviews: After identifying key stakeholders and their needs, I took a deeper dive into the problem by conducting face-to-face interviews with close to 1,000 smallholder farmers in Thailand and Pakistan. Talking with real customers is the best way to truly understand their problems.

Local nonprofit organizations were tapped to help gather farmers, who were then asked a range of questions related to banking, micro- and macroeconomic indicators, farm practices, and technology access. After the results were collected, they were analyzed to assess farmers' needs. This information was used as a starting point in the product design and development process and provided a baseline to help me measure the social impact of future interventions.

Findings: Our research showed that smallholder farmers have the following key needs.

- Products and services need to come with financing solutions and with sufficient training to ensure optimal use.
- Increasing incomes need to come with opportunities to grow larger farms and operations.
- Increasing productivity needs to come with access to markets.
- Fixing only one piece of the puzzle without considering the holistic system and the needs of myriad stakeholders will not solve the problem. A World Bank study showed that "successful projects address farmer constraints along the whole value chain," thus emphasizing the efficacy of integrated approaches to providing services for smallholder farmers.

Product design and development (PDD) framework: Using the PDD framework developed by MIT Professor Steven Eppinger (codirector of MIT System Design & Management), I moved from needs analysis and idea generation to product launch. I also identified a product launch framework designed to successfully develop and introduce new, innovative products into the real world. I was particularly interested in a mobile-based product since the mobile penetration rate for smallholder farmers in developing countries has recently risen rapidly. It is an undisputed fact that mobile phones can drive progress in developing and emerging markets.

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Lean methodology: We used the lean methodology of quickly getting a minimum viable product in front of early adopters, which enabled us to get product feedback quickly. This proved extremely useful in achieving product-market fit. Product iteration and frequent customer feedback are crucial steps in product design. As Reid Hoffman, founder of LinkedIn, famously said, "If you are not embarrassed by the first version of your product, you've launched too late."

Even though getting farmers to adopt new practices and products may seem daunting and costly, encouraging findings from the literature indicates that the value created by investing in such farmers' productivity dwarfs the costs involved.

The results: Based on the lessons learned and the systems tools utilized, I launched Ricult to help improve the lives of smallholder farmers in developing countries, starting in Pakistan. Ricult offers a mobile platform that provides high-quality farm inputs such as seeds, fertilizers, and other essentials to farmers on credit at affordable rates. By providing farm inputs as in-kind loans, we can ensure that the full loan is invested in high-quality, productive assets as opposed to misused in unproductive consumption.

At Ricult's core is its proprietary "Ricult Score," which uses a data-driven approach to assess a farmer's creditworthiness based on nontraditional data sources such as the farmer's expected crop revenue, mobile usage behavior, soil fertility, and social reputation. These data indicate thousands of subtle patterns of behavior that correlate with repayment or default.

Ricult also helps provide agronomy tests and services to improve farm yields and helps connect farmers with end buyers, which further reinforces the positive feedback loop, boosting results for the farmers.

Farmers have responded enthusiastically to Ricult because we provide loans at interest rates five times lower than what is typically available; we offer higher quality farm inputs at 30 percent lower cost, which also results in higher yields; and we offer a repayment schedule that matches the crop cycle. All of these benefits directly increase the farmer's income and livelihood.

Based on a World Bank study, growth in agriculture has shown to be three times more effective in reducing poverty than growth in other sectors. Ricult's first pilot market is Pakistan because it is one of the world poorest countries, with more than 60 million smallholder farmers. As a result of this pilot:

- farmers' operating costs have already decreased by 30 percent;
- yield has increased by 20 percent from the higher quality input;
- revenue has increased by 30 percent from direct selling to end consumers; and
- average income of farmers participating in the study has increased from $2 per day to over $3.60 per day—this translates to a more than $580 increase in income per year, enough for farmers to send their children to school and improve their quality of life.

Next steps: Problems faced by smallholder farmers are very similar across the developing world, especially in Asia. The natural next step for Ricult is to expand to nearby countries. The next target markets are Thailand, China, and India, which together are home to 200 million smallholder farmers. Along the way, Ricult team will continue to take a holistic approach to problems and develop innovative products that bring end-to-end solutions to smallholder farmers.

This work has tremendous potential to change societies for the better in the long term. More successful farmers will be better positioned to negotiate prices and contracts for themselves, allowing them to earn more income. This increased income can be used to increase farm productivity, educate children, and improve quality of life—potentially for hundreds of millions of people.

About the Author

Dr. Ellen Czaika is head of global engagement for Gamaya, a spinoff of École Polytechnique Fédérale de Lausanne that uses machine learning on hyperspectral imagery to help farmers increase their crop yields to feed the increasing global population. Czaika holds a PhD from MIT and two master's degrees: one in in applied statistics from the University of Oxford and one in engineering and management received as a graduate of MIT System Design & Management (SDM). Her doctoral research builds on her SDM master's thesis (outlined in this article) and investigates how quantitative models can be used in sustainability negotiations and decisions. She currently applies this interest in data-driven decision-making to the precision agriculture domain.

Lessons Learned from Using a Model in a Sustainability Negotiation

The challenge: Consider the partners in a supply chain working together to negotiate a more environmentally friendly end of life for their product. All five member companies want a more sustainable result, but they disagree on how to achieve it because they have different business strategies. The issues they are considering cover various aspects of sustainability: environmental protection, financial feasibility, and social impact. The challenge for these partners is to agree on a set of alternatives that advances them toward their respective business, environmental, and social goals.

Would a life-cycle assessment (LCA) model that allows the companies to test the emissions of their alternatives help them reach an environmentally friendly agreement that supports their diverse business and social goals?

The approach and tools: To test whether the use of a model can impact the negotiation process and outcomes—and if so, to measure by how much—I conducted an experiment using a serious role-play simulation game called the Cup Game.

There are several advantages to using this approach:

- Serious games allow participants to interact with each other as they see fit. This allows for more natural interactions than other experimental methods.
- An experimental method enables statistical analysis and makes it possible to test different conditions, such as giving some—but not all—negotiation groups an LCA model.
- Observations during the experiments and interviews with several participants afterward provide qualitative data about what participants experienced while negotiating.

The Cup Game role-play simulation is a stylized version of a real-life supply chain for used paper coffee cups. In this game, experimental participants attempt to negotiate a deal by playing one of five roles: coffee retailer, cup manufacturer, recycling company, composting company, or hauling (trash truck) company. Each gaming group (consisting of these five parties) negotiates five project management decisions for a pilot program that will assess end-of-life alternatives (composting or recycling) for the cups after consumers finish using them.

The structure of the Cup Game enables quantitative comparison of the negotiated outcomes.

- Each role has a unique point structure of "value" earned for each alternative.
- Each role has a unique point threshold participants must meet or exceed to enter into an agreement.
- Regardless of the role played, each participant independently receives instructions that he/she will receive bonus points if the final group agreement reduces carbon dioxide emissions below a certain threshold.

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The participants were diverse students and professionals from negotiation and/or sustainability-related fields. Seventy-four groups of five participants played the Cup Game. Seventy-three groups reached an agreement, and one did not.

The LCA model calculated the amount of carbon dioxide emitted from various ratios of recycling and composting the used paper cups, taking into account the carbon dioxide emitted along the driving distances to the respective recycling plant and composting facility. It was spreadsheet-based. Each party received at least one data point pertinent to the LCA, regardless of whether the group was randomly selected to receive the LCA itself or not. Since all groups had access to the required data, groups who did not receive the LCA could create it themselves.

The results: Although only 50 percent of the five party groups were given the LCA model, an additional 30 percent of the groups each created the LCA for themselves while negotiating. Statistically, significantly more of the groups that created their own model (44 percent) reached favorable agreements—ones that either minimized carbon dioxide emissions or, mutually exclusively, maximized the value the negotiators earned—than groups that used the given, expert-made model (25 percent).

Of the groups that reached a favorable agreement, half (50 percent) of the groups creating a model selected the environmentally strongest agreements (reducing carbon dioxide emissions the most), compared to only 38 percent of groups using the expert-made model and 25 percent of groups not using a model.

All other factors—such as the environmental protection of a negotiated agreement—being equal, negotiation groups do better in the game if they reach an agreement with higher value—balancing the environmental, financial, and social factors involved in sustainability. Models affected success in the following ways:

- Groups that used a model outperformed those that did not use a model in terms of the value earned. See Figure 1.
- Groups that created their own model reached agreements that protected the environment more than groups that
  used the given model who, in turn, reached agreements that protected the environment more than the groups that did not use a model.

Not all the groups that employed a model used it in the same way. Some used it while they were creating tentative agreement packages to test the amount of carbon dioxide each alternative would save. Others employed it at the end of the negotiation to verify that a provisional agreement would reduce carbon dioxide emissions below a certain threshold. Groups that used the model to test alternatives as they created an agreement scored higher than those that used the model to verify a provisional agreement.

Interestingly, using the model did not prolong the negotiation, even when group members spent time during the negotiation to create their model (see Figure 2). This is particularly important because fear of a lengthy process deters some from negotiated approaches to decision-making.

Negotiated approaches are particularly beneficial because they allow for decisions that address a combination of different issue types, such as those related to scientific principles (like the amount of carbon dioxide emissions), business strategy, and human values and personal preference. Furthermore, each party has his/her own unique perspective of the issues at hand. Collectively, individualized perspectives allow for value creation, the possibility of one party giving up something that is less important to him/her, but very important to someone else, in order to gain something he/she perceives as more important. Not surprisingly, multi-issue negotiations such as those that take place in the Cup Game are systemic and often cover many facets of an organization's life.

Next steps: The experiment described in this article is set within a sustainability context. As with all experiments, it doesn't perfectly represent the real world, and results may be specific to the situation at hand (i.e., generalizing the findings to other settings may not be warranted). With that caveat, these results suggest that real-world negotiating parties might benefit from using models in sustainability and other contexts, particularly if they themselves create the model. Follow-on research can study non-lab negotiations and other negotiating contexts and investigate the mechanism by which model use helps negotiators.

From a systems thinking perspective, using a model while negotiating gives parties the possibility for feedback about their potential choices sooner than if they had to wait to see the consequences of implementing their negotiated agreement. This allows them to compare different agreement packages in a consequence-free and responsive way. Using the model's feedback, they can select alternatives that best meet their objectives, in a "fail early, fail often" design-thinking approach.

Dr. Czaika wishes to thank Starbucks Coffee Co. for partial funding of this research; her advisor, Noelle Selin; Larry Susskind; Ofer Sharone; the Paper Recovery Alliance; and MIT Sloan's Leadership Lab: Leading Sustainable Systems faculty Wanda Orlikowski, Peter Senge, and Sinead O'Flanagan.

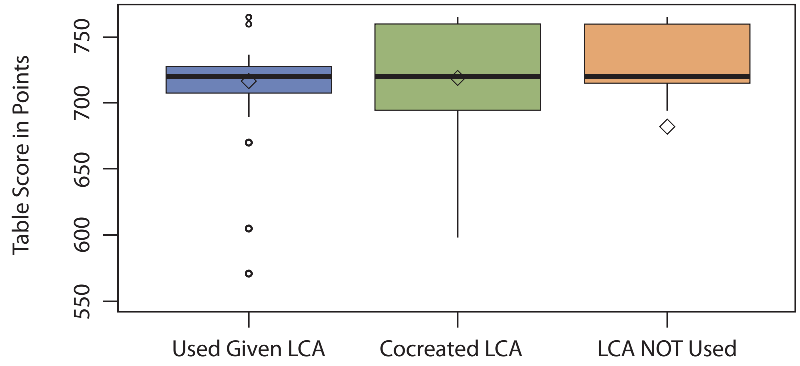


Figure 1. Model-using groups of negotiators (blue and green box plots) had higher average scores (marked by diamonds) than groups that did not use the model (orange box plot) in this sample, though statistically they are the same. Groups that created their own models and those that used the expert-made model had statistically equal median scores (the bold lines inside the colored boxes). Although this point is not pictured, the group not using a model contains the one table that did not reach agreement.*

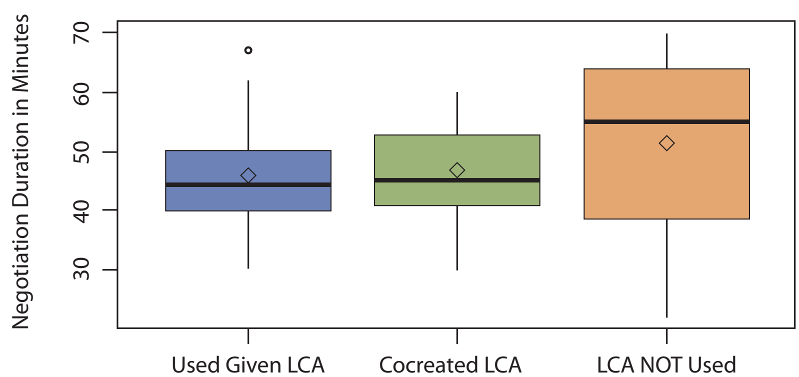


Figure 2: Negotiation groups that used a model (blue and green box plots), even those that created their own model during the negotiation (green box plot), reached agreement more quickly than those that did not use a model (orange box plot) in this sample. Statistically, the groups took the same amount of time to negotiate.*

*Source: Czaika, Ellen, and Noelle E. Selin. "Taking Action to Reduce Waste: Quantifying Impacts of Model Use in a Multiorganizational Sustainability Negotiation." *Negotiation and Conflict Management Research* 9.3 (2016): 237-255.

Almost 200 SDM alumni, students, and staff gathered to celebrate Pat Hale's retirement as SDM executive director and to thank him for his leadership over the past 12 years.

Executive Director Pat Hale Retires from SDM

By Lois Slavin, SDM Communications Director

After 12 years of nurturing and building the MIT System Design & Management (SDM) program, Pat Hale announced his retirement as executive director, effective November 28, 2016. His decision marked the end of a remarkable tenure in which he led SDM to become the world's preeminent graduate degree program for systems-focused technical leaders.

Hale joined SDM in 2004 to help establish the SDM Certificate Program in Systems Engineering and Product Development. Shortly thereafter, he became director of the SDM fellows program and later executive director of SDM. While at SDM, Hale served as president of the International Council of Systems Engineering from 2008 to 2010. He holds a master's degree from MIT in ocean engineering, an MBA from National University, and a BS in oceanography from the University of Washington.

"In many ways, SDM reflects Pat," said Professor Warren Seering, SDM engineering codirector. "SDM evolved and succeeded thanks to his passion for systems, his dedication to his job and MIT, his love for working with students and alums, and his desire to help everyone around him."

Professor Steven D. Eppinger, SDM management codirector, added, "Under Pat's watch, SDM has become an acknowledged leader in interdisciplinary graduate education for experienced technical professionals—here at MIT, in industry, and around the world."

Joan S. Rubin, former industry codirector for SDM, has been named SDM executive director and senior lecturer. (See related article on page 3.)

Pat Hale and SDM Codirector Steven D. Eppinger

Pat Hale with (left to right) SDM Executive Director and Senior Lecturer Joan S. Rubin, and SDM staff members Dave Schultz and Jon Pratt.

Kate Cantu Wins 2016 SDM Leadership Award

On September 27, 2016, MIT System Design & Management (SDM) Industry Codirector Joan Rubin* announced that Kate Cantu won the annual MIT SDM Student Award for Leadership, Innovation, and Systems Thinking. The announcement was made during the annual SDM student-alumni networking session at Morss Hall on the MIT campus.

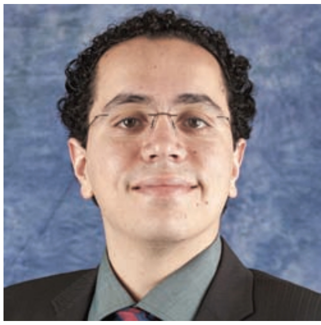
Kate Cantu, SDM '16

Created by the SDM staff in 2010, the award honors a first-year SDM student who demonstrates the highest level of strategic, sustainable contributions to fellow SDM students and the broader SDM and MIT communities; superior skills in leadership, innovation, and systems thinking; and effective collaboration with SDM staff, fellow students, and alumni.

The winner receives a monetary prize.

Cantu, a member of the SDM class that entered in 2016, was cited for numerous achievements, including the following.

- She served as program manager for MIT's CubeSat team, which competed in the Cube Quest Challenge, a small satellite competition run by the National Aeronautics and Space Administration (NASA). In this role, she supervised several MIT undergraduate and graduate students while integrating 25 high school students into the team. She led the team to a second-place finish in one of four tournaments held to select satellites for an unmanned lunar flyby mission planned for launch in 2018. (Her team is still in the ongoing competition.)
- She co-led the annual SDM Tech Trek to Silicon Valley, in which 25 students and five faculty visited nine companies in just five days.
- She co-led SDM's "Not a Drone" boat entry for MIT's Crossing the Charles Competition. She helped plan and execute the boat's design, build, test, and operation.
- She conducted thesis research resulting in a proposed new model-based systems engineering framework of methods and tools for better aligning technology development for the US Department of Defense's space enterprise.
- She served on the SDM Student Leadership Council; was a panelist for two SDM information sessions; was a panelist and mentor at a US Air Force career day; and participated in an in-class panel on model-based systems engineering, where she shared the US Air Force perspective.
- She led a student seminar titled "A Day Without Space."



Leo Barlach, SDM '16

Beyond the MIT community, Cantu organized and/or volunteered for several activities at her children's school, including developing and leading a rocket experiment for 90 second-graders as part of Science Day.

Vikas Enti, SDM '16

In addition to Cantu, this year's nominees included Leo Barlach and Vikas Enti. Barlach was recognized specifically for his leadership roles with the 2016 MIT Sustainability Summit, the SDM Student Life Council, the Sidney Pacific Graduate House, SDM's participation in the Crossing of the Charles celebration, and for his volunteer work with the Gordon Engineering Leadership Program.

Enti was commended for his leadership roles as associate director of the MIT $100K Startup Competition and as a co-leader of the fall and spring SDM Tech Treks, as well as for serving as Amazon Robotics' MIT liaison.

All nominees and the winner are selected by the SDM staff, with input from the first-year SDM community.

* Rubin was recently named executive director of SDM. See story on page 3.

SDM Fellows Visit Bose, Shell TechWorks

On November 16, 2016, more than 25 members of the MIT System Design & Management (SDM) community embarked on a daylong Greater Boston tech trek to Bose Corporation and Shell TechWorks. Held twice yearly on the East and West coasts, tech treks enable SDM students to learn from executives in best-in-class companies about the complex, interdisciplinary challenges they face. The fall 2016 trek was spearheaded by SDM fellows Shweta Jindal, Christian West, and Jose Garza, who serve as tech trek chairs within SDM's Student Leadership Committee.

Among the products demonstrated for SDM fellows during the November 2016 tech trek visit to Bose Corporation was the BOSEbuild Speaker Cube (pictured), a build-it-yourself Bluetooth speaker for children ages 8 and older.

First stop: Bose Corporation headquarters in Framingham, MA, where SDM alumnus Rajesh Mishra, a Bose technology manager and software and systems architect, welcomed the group. Students heard an introductory talk that covered Bose Corporation's history, the business philosophy of founder and chairman Dr. Amar Bose (who was also an MIT professor); and learned that a gift from Bose had made MIT the company's majority shareholder.

A sneak peek at new products:

SDM fellows then got an up-close look at several of the company's new products, including the Bose Ride, a seat suspension system for heavy trucking that reduces driver fatigue (students tested a working prototype, pictured above); BOSEbuild, a build-it-yourself Bluetooth speaker for kids ages 8 and older (the product was demonstrated for the SDMs); and a yet-to-be-released personal audio amplification product.

They also toured Bose's Rapid Prototyping Development Center, a recent addition to the company's product development capabilities. This maker space, equipped with state-of-the-art manufacturing equipment, includes 3D printing, injection molding, laser-cutting, and more.

They then learned about the company's community relations initiatives, including matching donations, volunteerism, and more, all centered on ensuring that Bose is a good corporate neighbor in the communities where it operates. The visit concluded with a networking lunch that included a brief recruiting session.

The next stop was Shell TechWorks in Cambridge, MA, not far from SDM's program office in Kendall Square. Talent Manager Robert Madore welcomed the group, presented an overview of the company, and described how it generates value for its parent by applying "de-risked" technologies to some of its most complex engineering challenges. Defining de-risked technologies as those that have been previously tried, tested, and used in other industries, Madore explained that they consequently carry less risk than those that have not been tested at all.

An interdisciplinary approach:

SDM fellows learned that in order to approach interdisciplinary challenges, Shell TechWorks employs about 35 engineers from diverse backgrounds. These include SDM alumnus Brian London, who serves as manager of system architecture, and MIT alumnus Adam Vaccaro, who is the manager of mechanical engineering. Together they conducted an interactive discussion with the SDMs in which they described several projects, outlined how challenges were addressed using lessons from SDM, and shared results.

Students then toured the office, which was designed to promote a skunkworks-like atmosphere. Like Bose, it was equipped with a maker space (although smaller), where equipment is designed, developed, tested, and refined before deployment to the field. The visit concluded with a networking/recruiting session with Shell TechWorks engineers.

SDM fellows gather at Shell TechWorks in Cambridge, MA, during the November 2016 tech trek. The visit included meeting with leaders and learning about the Kendall Square company's technology investment strategy.

2017 SDM Spring Tech Trek

During SDM's annual five-day spring tech trek to San Francisco's Bay Area, fellows will visit several of the world's most innovative companies to learn about the work they do and the complex challenges they face. Career opportunities will also be discussed.

As of press time, these organizations include: Amazon.com, Continental Tire the Americas, E.&J. Gallo Winery, Google Inc., Intel Corporation, Planet Labs Inc., Tesla Motors, and Visa Innovation Center.

The trek will take place on March 27-31, 2017. If your company is interested in participating in this or future SDM Tech Treks, please contact SDM Executive Director Joan S. Rubin at jsrubin@mit.edu or Director of Career Development and Recruiting Jon Pratt at jonpratt@mit.edu.

2017 spring sdm calendar

AVAILABLE

> on demand

Virtual SDM Information Session:
Learn more about MIT's System Design & Management (SDM) program and its master's and certificate offerings.
Available on demand at www.youtube.com/user/MITSDM

> SDM Pulse online

Read current and past issues of the *SDM Pulse* on the web, visit **sdm.mit.edu/pulse/**

Details and registration information for all events are at **sdm.mit.edu**.

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/.**

February 27, 2017

A Smart City Pilot in Boston: Collecting Human-Centric Urban Data
(Recording available on demand at **sdm.mit.edu/news-and-events/webinars/**.)
Nissia Sabri, CEO and cofounder, BitSence; SDM alumna

March 13, 2017

Providing Medical Devices as a Service to Hospitals and Clinics in Nigeria: A Systems-Based Approach to Healthcare, Job Training, and New Economic Models
Oluwasoga Oni, cofounder, MDaaS; SDM alumnus

March 27, 2017

Applying Systems-Based Methods to Challenges in Product Development, Management, and Organizational Dynamics
Ron Pepin, managing director, Pepin Consultants LLC; SDM alumnus

April 10, 2017

Model Use in Sustainability Negotiations and Decisions
Ellen Czaika, PhD, head of global engagement, Gamaya; SDM alumna

April 19, 2017

Adventures with Strategy, Systems Thinking, and Business Frameworks in the Real Corporate World
Aravind Ratnam, head of connected vehicle products, Wind River; SDM alumnus

April 24, 2017

ElectroKite: A Systems Approach to Wind Energy
Burak Gozluku, SDM fellow and research assistant, MIT

May 8, 2017

Best Practices for Water Use in Thermoelectric Facilities
Jorge Moreno and Donny Holaschutz, cofounders, inodú; SDM alumni

May 22, 2017

Design Quality and Software Economics in the Airline Travel Industry
Daniel Sturtevant, PhD, CEO, Silverthread, Inc., and Harvard researcher, with Martin Jouvenot, expert in software engineering, Amadeus IT Group

> **2016 SDM Conference on Systems Thinking for Contemporary Challenges**
> Watch videos of all speakers. **https://www.youtube.com/user/MITSDM/playlists**

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