The predictive production system: The future of making

What could your factories achieve if your whole organization had access to timely, actionable intelligence? That's the promise of systems combining analytics, big data and the Internet of Things.

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In an era of quick and often simplistic analysis, our clients tell us that what they most urgently need is perspective. That's particularly the case for innovations that promise significant, lasting change.

Accordingly, in this McKinsey-curated discussion, our panelists have brought their deep perspectives based on experience spanning decades in batch, continuous, and discrete-products manufacturing systems. That background is invaluable in framing a discussion of what's introduced here as the predictive production system (PPS), which combines big data, advanced analytics, and the Internet of Things (IoT) into a "social network of things."

PPS has the potential to transform asset productivity as we know it. Organizations will be able to make better decisions that will optimize not just individual machines, but whole production systems—thereby increasing operational resilience and creating lasting value.

For this discussion, we adapted the classic Delphi method, a systematic, interactive forecasting method in which a panel of experts answer questionnaires in two or more rounds. The format encourages participants to revise their earlier answers in light of the replies of other members of the panel. We also recognized that really good questions are those that may not be answered immediately. Indeed, we've allowed ample time for our panelists to reflect on the questions deeply.

McKinsey: *What do you see as the most important implications of PPS, not just for products and services but also for how companies operate?*

Jay Lee: Fundamentally, PPS analyzes data from sensors and previous records, and establishes value relationships between parameters and outcomes of a product or process. In that way, it combines digital technologies to make decision making more transparent, predictable, and precise. So, for example, John Deere has developed soil moisture sensors that help farmers increase yields through precision farming technologies. Alstom predicts the remaining useful life of trains, infrastructure, and signaling assets, while Komatsu remotely monitors its bulldozers for just-in-time maintenance services.

PPS also transforms how companies make decisions, with evidence-based approaches that use predictive-analytics tools to establish relationships, estimate confidence values, and help define risks and consequences. Over time, PPS can supplant experience-based decision making that relies mainly on the individual's judgment from their previous experiences.

Brian Weiss: As a member of the government, my views on PPS's impact for non-government organizations is from an outsider's perspective. I see PPS as enabling organizations to be more flexible and

responsive to both upstream supply chain challenges and downstream consumer demands.

About our panelists

John Fleming retired from Ford Motor Company in 2015 after 48 years. At the time of retirement, he was Executive Vice President for Manufacturing and Labor Affairs, and before that he was Chairman and CEO for Ford in Europe and Chairman of Volvo. Since retirement, he has been consulting and presenting on Industry 4.0, both independently and for Frost & Sullivan. He may be reached at jflemin8@gmail.com.

Dr. Jay Lee is Ohio Eminent Scholar, L.W. Scott Alter Chair Professor, and Distinguished University Professor at the University of Cincinnati and is founding director of National Science Foundation (NSF) Industry/University Cooperative Research Center (I/UCRC) on Intelligent Maintenance Systems, which is a multi-campus NSF Industry/University Cooperative Research Center. His current research focuses on predictive big data analytics and cyber-physical systems, prognostics, health management, and smart asset-management systems. He also serves as a senior advisor to McKinsey & Company. He may be reached at jay.lee@uc.edu.

Dr. Brian A. Weiss is the Project Leader of the Prognostics, Health Management, and Control project at the United States National Institute of Standards and Technology (NIST). His efforts are focused on developing measurement science to verify and validate monitoring, diagnostics, prognostics, and maintenance technologies and strategies for smart manufacturing. He may be reached at brian.weiss@nist.gov.

The power of PPS lies in how it generates timely, actionable intelligence throughout an organization. Managers and leaders can therefore make better-informed decisions about their areas of responsibility, based on the intelligence that other leaders and managers are continuously generating.

Accordingly, the success of PPS within an organization will depend largely upon the level and number of personnel that embrace it.

John Fleming: It will take many years for a transformation from reactive to predictive decision making to take place. At best, companies will start by testing PPS on constraint operations—the chokepoints that constrain a process. In an automotive factory, for instance, the specific constraint could be the framing system in the body shop. That would be my choice for introducing real-time monitoring and feedback, which will test the tools and deliver results quickly.

These changes will add up. I believe that PPS-based insights could help today's lean companies eliminate at least 30 percent more waste, especially when new factories are planned and operated in this new predictive world.

McKinsey: *How do you see PPS changing today's competitive dynamics?*

Jay Lee: I think PPS will become increasingly critical to increase responsiveness and transparency from the factory floor on up.

Brian Weiss: Once a few organizations start adopting PPS, other companies will start to take notice. Companies that have PPS will

quickly discover that they can do more with other "haves", especially in their supply chain. "Have-nots" will be forced to make a choice: adopt PPS, or lose partners—and perhaps disappear.

John Fleming: Over time, the competitive pressure to adopt PPS will likely rise. For example, a more predictive operating environment will reduce overspending on infrastructure, enabling factories to be smaller and safer while delivering better quality. Transformed companies will be leaner and therefore more competitive.

McKinsey: *What effects do you foresee on the landscape of partnerships and joint ventures?*

Brian Weiss: Companies that are adopting PPS will be more likely to partner with companies that have also adopted PPS, in part so that both sides can take better advantage of the timely, actionable intelligence that PPS techniques generate. That leads to a more collective mindset, in which companies share pertinent intelligence with one another to build on one another's insights.

This could lead either to greater dependence on the other organization. But, if an organization uses the collective intelligence to develop detailed models, it can ultimately achieve independence: the models will support better decision making when intelligence is unavailable, corrupted, incomplete, or uncertain.

John Fleming: Companies that already understand how to use enormous amounts of data will have an initial advantage—but this may not be sustainable as analytics becomes more mainstream. Instead, manufacturing companies that understand their design needs may have an increasing advantage. I've already seen some automotive companies use their own data to regain more control over their design processes in areas such as electronics, in order to improve quality and reduce costs.

McKinsey: *Do you foresee a point when PPS becomes an industry norm?*

Jay Lee: Like any new idea, PPS technologies will need to support clear objectives, such as cost reduction, increased quality, or improved efficiency. The execution of PPS could hit a wall if it isn't aligned with these types of objectives.

Brian Weiss: We won't reach that point until numerous manufacturers demonstrate long-term success with it.

John Fleming: I think we sometimes misunderstand where industry actually is today. In the eyes of some people, manufacturing is fully leaned-out, with super-well-trained people who are organized in the right way delivering leading-edge productivity. In some companies that is the case. However, for many companies the theory is understood but not practiced. These companies have an enormous opportunity today before we even get to PPS.

So in my opinion, we need to think of PPS as putting more tools in the toolkit for people to use in the future.

McKinsey: What are the three misunderstood claims and three underreported developments in PPS today?

Jay Lee: For me, the lack of analytics skills in the workforce is the first. The second issue is the misunderstanding of IoT and cloud computing, which are often presented as if they are solutions all on their own. All of

these types of developments—IoT, Industry 4.0, and the industrial Internet—are potential mechanisms to achieve smart products and services, but they are not the only solutions. To me, the correct vision is the "Internet of the Right Things."

The third problem is the wrong definition of big data. Many people think that the most important task is to collect data. That's wrong. I often say that there are three fundamental issues of big data: broken, bad, and background. Data cannot bring visible value through analytics if these three weaknesses are not addressed.

Brian Weiss: From my perspective, the largest misunderstood claim regarding PPS is the value of big data. The anti-big-data perspective would be to capture only the data I know I am going to need and use. Conversely, the pro-big-data perspective would be to capture as much data as possible whether or not I know exactly if, when, or how I'm going to use it.

It's about understanding the trade-offs. Pro-big-data means you are likely to spend more money upfront with the hope that it will pay off over time. Conversely, anti-big-data will be cheaper to implement and maintain, but will be more likely to miss catching some faults and failures within your manufacturing process during its lifecycle. That could lead to greater costs in the long run.

McKinsey: *What role will corporate and business-unit leaders play in taking full advantage of PPS?*

Jay Lee: The two main goals of asset productivity are zero unwanted downtime and worry-free operations. Corporate leaders must support these objectives with a meaningful vision so people can understand why PPS is important.

Brian Weiss: Bringing more minds into the equation, especially those that buy into PPS, will also be beneficial. Diversity in background, experience, and technical skills will provide this team with a competitive advantage. Mixing people who (proverbially) speak different languages, such as operations technology and information technology personnel, will help people better understand what other individuals in the organization need to be successful. In turn, that gives everyone greater insight into what the overall organization needs to be successful.

John Fleming: PPS should be recognized as one piece of a digital strategy, and part of the responsibility of a single digital leader. That individual will help guide the company through the development and implementation of the digital strategy.

McKinsey: *What do you see as the major barriers to PPS, and the ways successful companies can overcome them?*

Jay Lee: Many companies are trying to install the underlying technologies without knowing what their objectives are.

Brian Weiss: Some organizations stigmatize failure too heavily. PPS can be a radical change, so it's unlikely that the initial PPS design and implementation will be perfect. Of course, allowing for failure is not a license to conduct haphazard design—the design process should still be rigorous, documenting the potential risks a design entails.

An additional final barrier is the lack of specific PPS standards and guidelines. Any organization that wants to adopt PPS and benefit from

other organizations' knowledge would be well-served by participating in activities that support the design and development of PPS standards. When diligently supported by diverse organizations coming together, the standard-setting process can generate invaluable guidance and common practices

John Fleming: I'd say the major barriers are the same as always: Change management, people capabilities, cyber security, knowledge and understanding, and time.

McKinsey: *How can senior executives get their hands dirty with raw data?*

Jay Lee: In data management, IT departments and CIOs have traditionally focused on connecting and collecting data. With PPS, they'll need to build their capabilities in converting data to value, using analytics techniques that are substantially more advanced than statistical models.

Brian Weiss: A purposeful form of "management by walking around"—which in a lean context is often called "go and see" or a "gemba walk"—lets executives capture raw data in person, rather than sitting in a meeting and getting aggregated data from direct reports. Observing specific production operations, such as situations that trigger sensor readings, can generate the type of up-to-the-minute intelligence that creates practical value.

McKinsey: *How do corporate leaders bridge the gap between data analytics and business opportunities?*

Jay Lee: To achieve real impact, data scientists need domain knowledge on real-world operations. A core team would consist of data science and data value experts working together to reduce communication barriers.

Brian Weiss: Organizations should invest in personnel who can speak the differing languages of its operations—and, in parallel, should educate everyone on a common organizational language that encompasses overall company goals, objectives, and target consumers.

Building a team of translators who can interact with all of these different departments would also substantially improve communications. Some organizations promote rotational assignments as a way to strengthen these capabilities, producing many translators who become more adept at addressing different challenges throughout the organization.

McKinsey: *How will evolving technologies, such as visual cognition and natural-language processing, change the near-term outlook?*

Jay Lee: When combined with augmented reality and virtual reality, predictive analytics can easily make today's trial-and-error operations much more precise. For example, supplementing automated optical inspection with predictive analytics would allow people to mine the root causes of identified faults, and further pinpoint areas for correction or improvement.

Brian Weiss: Advanced visual cognition would ideally enable the collection of multiple information streams from the same vision system. This single vision system could be used for sensing the world: for equipment monitoring, diagnostics, and prognostics, for operator

safety, and for quality inspection. Although such a system might start out being somewhat expensive, the cost-benefit ratio could be high enough to make implementing it profitable over time.

McKinsey: *Name three job titles in 2025 that do not exist today. What do they do?*

Jay Lee: Data technologists will have special expertise in data connection, conversion, cognition, and configuration. Analytics technologists and value explorers will have the insights and innovation thinking needed to identify and analyze unfilled gaps between customer needs and the business.

Brian Weiss: Robot training specialists (RTSs) will be responsible for teaching new tasks to robots, which today requires a fair amount of hard-coding. By 2025, technologies will have advanced so that the RTS likely be able to train a robot either by verbally describing the task, demonstrating it, or inputting a "task operations document" that the robot converts into physical actions.

The robot maintenance technician would be responsible for teaching robots how to perform maintenance on themselves or other robots. This would also include teaching the robots to recognize faults and failures in themselves (or others) that they are capable of addressing. The robot controllers would have the necessary machine learning skills to adapt to new faults and failures as they occur, based upon their understanding of known faults and failures, the faulty robot's job function, and the available spare-parts inventory.

McKinsey: *What other advances—in machine learning and robotics, additive manufacturing (also known as 3D printing), autonomous vehicles, IoT, and so forth—do you believe could accelerate the adoption of PPS?*

Jay Lee: We need smaller and smarter sensors to perceive the invisible physics of many systems. Edge computing connected to smart sensors will make the feature extraction for faster processing. Easy-to-use embedded algorithms should be in an open-source environment so engineers and practitioners can easily use them for smarter applications.

Brian Weiss: Autonomous fine-motor control and greater situational awareness within the manufacturing environment would further propel PPS into the factory■

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