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Development of the University of Kentucky – Toyota Research Partnership: Monozukuri: PART I

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INTRODUCTION

Monozukuri is a Japanese word consisting of "mono" which means "products," and "zukuri" which means "process of making or creation." However, the word means more than simply making something; it has overtones of excellence, skill, spirit, zest, and pride in the ability to make things very well. Monozukuri is not mindless repetition; it requires creative minds and is often related to craftsmanship, which can be learned through lengthy apprenticeships rather than the structured course curricula taught at traditional schools. In that sense, monozukuri is an art rather than science. However, science plays an important role in monozukuri. This article discusses how important it is to have craftsmanship, technology, and scientific principles and practices when we want to have successful monozukuri and teach students with monozukuri.

Monozukuri can be done individually or as a team. The historical aspect of monozukuri was addressed by F. Cho in his article: "Toyota Production System (TPS)," in relating traditional craftsmanship to modern manufacturing systems. In his article, Cho mentioned a continuous improvement principle, known as Kaizen as a basic and guiding principle of the Toyota Production System, in which problem-solving is emphasized by finding the root cause. Industrial problems can be either system-related or process-related. A good example of a production system is TPS (Figure 1) whose concept consists of people, machines, and material as input elements. The production process includes, but is not limited to, stamping, forging, machining, welding, coating, etc. Each can be an independent research subject. When they occur, regardless of type, the monozukuri system will create defects or delay the production time. Both problems create waste. Therefore, the Toyota Production System constantly and systematically looks for all types of waste to be eliminated in order to improve the production (monozukuri) system.

In this two-part article, I adopt Cho's definition of monozukuri to cover the following:

- the University of Kentucky's Industrial Application and Engineering Science research group;
- the evolution and revolution of monozukuri research;
- research for development for monozukuri;
- three scientific tools and professional intuition (craftsmanship) for monozukuri;
- the computational method,
- Genchi-Genba, for monozukuri; and
- Vortecone invention as an example of team work monozukuri.

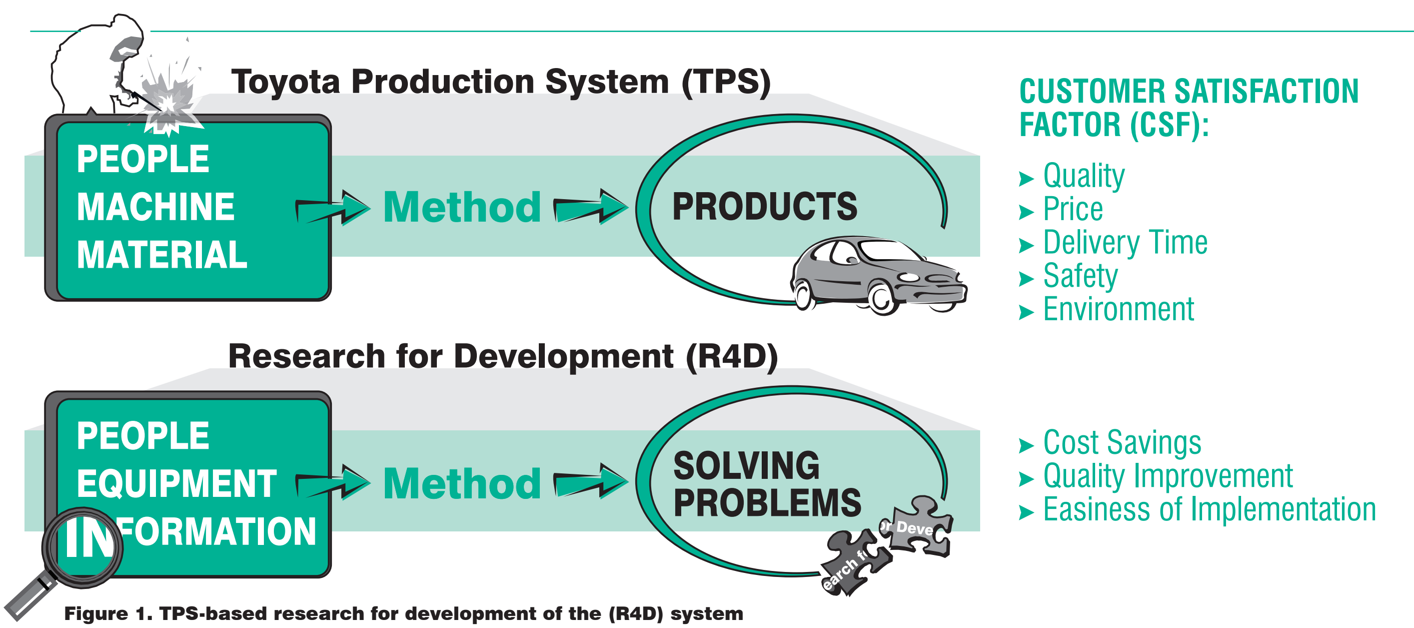

Figure 1. TPS-based research for development of the (R4D) system

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IAES CENTER AND ITS OPERATIONAL PRINCIPLES FOR MONOZUKURI

Let me begin with introducing IAES (Industrial Application and Engineering Science at the University of Kentucky) and our operational principles that connect us to each other in relation to monozukuri research. The name, Industrial Application and Engineering Science, reflects our group's philosophy. We are the engineers' group that can solve industrial problems using scientific principles and methods, and deliver value-added solutions to customers. IAES was formed in 1999 to cope with ever increasing demands on sponsored research from various industries and government agencies.

We have formed a team of international experts who can cover wide areas of research because no industrial problems are alike. Teams of researchers who have diversified areas of expertise can better solve industry's projects than teams of researchers who share the same expertise because industry's problems are open-ended and nothing like textbook problems, which guarantee that one correct solution exists for each problem. Solutions to industry's problems will be evaluated by the cost, implementation timing, and the resulting quality of improvement that the solution can render.

Three types of talent are required to conduct new-product development:

- individual talent for basic research,
- teamwork for projects, and
- human relationships for marketing.

Industry's problems may be categorized into two types. The first is the short term project in which a quick solution is supplied to help industry with day-to-day operations while the second, the long term project, requires a major improvement or even a transformation in operations. Both short term and long term projects require solutions that add value to a company's products or processes. At IAES, we work together to find the value-added solutions that help a company reduce costs and improve quality. **Figure 1** depicts the system IAES uses to solve industry's problems, adopted from the Toyota Production System in automobile manufacturing. Although IAES can conduct both short term and long term projects, our strength is our ability to create new ideas that can bring fresh and even revolutionary solutions to long term problems.

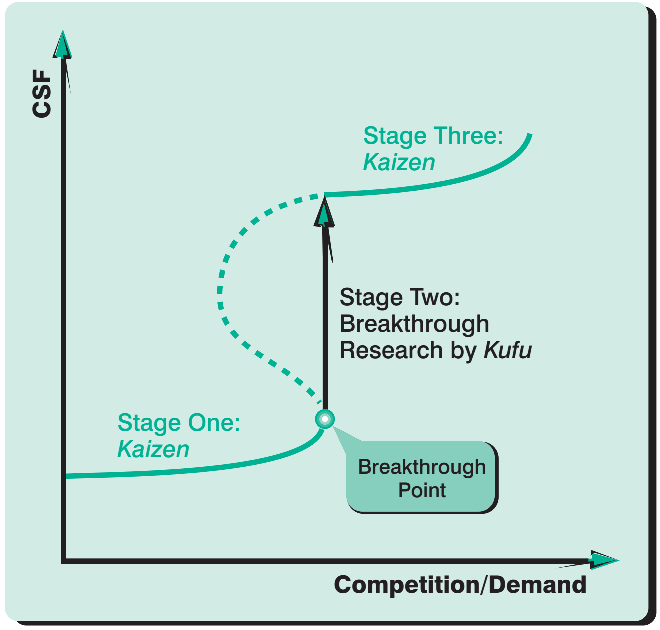

Figure 2. Research for development function theory (see also our web site: http://ptc.engr.uky.edu).

EVOLUTION AND REVOLUTION IN RESEARCH

Technology development can be either slow and evolutionary or abrupt and revolutionary. Kaizen is an example of the first and research breakthrough is an example of the second. **Figure 2** illustrates typical progress in technology development as a function of time, where evolutionary progress is made by the continuous improvement of Kaizen and revolutionary progress is made by major breakthroughs in research.

The solution for the short term project is usually a result of Kaizen effort, while the solution for the long term project often requires revolutionary thinking and solutions. There may be several factors that can contribute to technology revolution. Among them, two major factors are to look at problems in non-traditional ways and creating new ideas to find solutions. The second is to look at the problem from the generalist's point of view. To take the fresh-look-at approach, we must have scientific curiosity: "Ask why things are," as well as engineering creativity: "Dream of things that were not and ask why not."

To have the generalist's viewpoint, researchers must have a wide range of knowledge in science and engineering. Researchers with this broader scope of knowledge can see the entire forest before identifying the problem in individual trees. This global view will help to see how the obtained solution, when it is implemented, can influence the landscape of the entire forest.

RESEARCH FOR DEVELOPMENT (R4D) AND MONOZUKURI

There are two approaches of conducting research to develop technology: Research and Development (R&D), and Research for Development (R4D). As the name suggests, there is no clear linkage between "R" and "D" for R&D, thus increasing a hidden risk of disparity between the research and resulting development. When mismatches occur, precious resources and time are wasted.

Under R4D, as the phrase indicates, research is performed simply for technology development. This simple principle often is difficult for academicians to follow because academic researchers are accustomed to conducting research based on their interests, which can help develop their academic careers, but may not directly help solve industry's problems. Another inhibitor can occur because academic researchers are reluctant to step out of their narrow research territory due to the American university system of evaluating faculty performance in research publications where in-depth knowledge is emphasized and wide breadth of knowledge is not rewarded. Industry's problems, however, require the breadth of the generalist view because many inventions and technology breakthroughs were made by shifting paradigm from one area to the other. Another important element in R4D is teamwork. According to Emori (1998), the R&D approach is the typical result of a multi-disciplinary team where all members participate by contributing their expertise, but where a true integration as a cohesive single team is never achieved.

ENGINEERING EDUCATION FOR MONOZUKURI: THREE SCIENTIFIC TOOLS AND PROFESSIONAL INTUITION

To effectively conduct research and technology development, we conduct experiments (both full scale and scale

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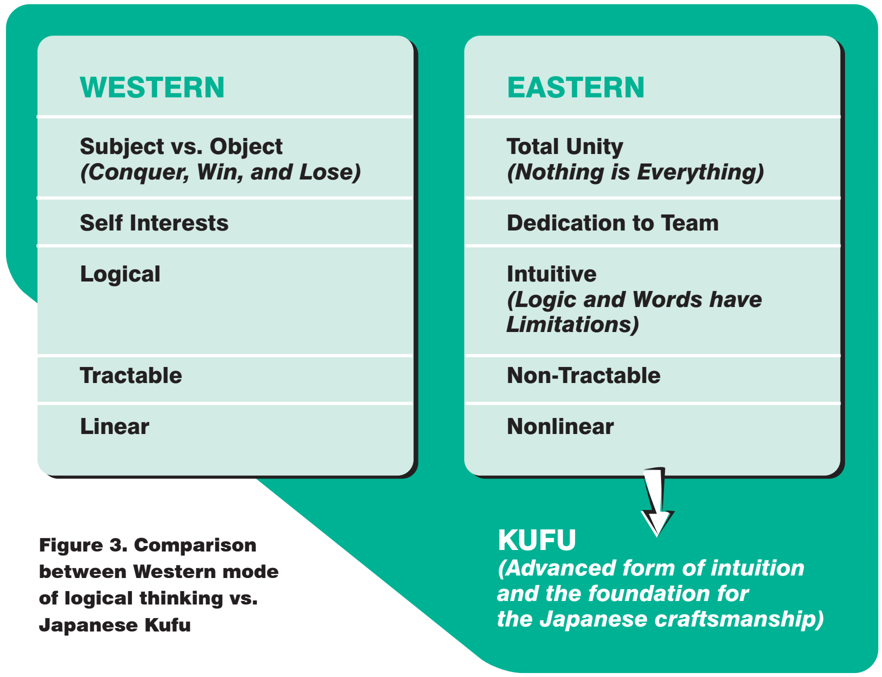

Figure 3. Comparison between Western mode of logical thinking vs. Japanese Kufu

model), evolve theory, perform computation, and use professional intuition. Readers may be familiar with the first three traditional tools, but not the fourth one and may require some explanation.

The fourth tool is not well known to scientific communities, although it has been used for years by scientists, engineers and skilled craftsmen. I call it Kufu, the term that was used by D.T. Suzuki in his book: Zen and Japanese Culture. The following provides some background information on how kufu (professional intuition) plays an important role in the breakthrough and discovery processes of scientific research and technology development.

"The term kufu is the most significant word used in connection with Zen and also in the fields of mental and spiritual discipline. Generally, it means 'to seek the way out of a dilemma' or 'to struggle to pass through a blind alley.' A dilemma or a blind alley may sound somewhat intellectual, but the fact is that this is where the intellect can go no further, having come to its limit, but an inner urge still pushes one somehow to go beyond. As the intellect is powerless, we may enlist the aid of the will; but mere will, however pressing, is unable to break through the impasse. The will is closer to fundamentals than the intellect, but it is still on the surface of consciousness. One must go deeper yet, but how? This how is kufu. No teaching, no help from the outside is of any use. The solution must come from the inmost. One must keep knocking at the door until all that makes one feel an individual being crumbled away. That is, when the ego finally surrenders itself, it finds itself. Here is a newborn baby. Kufu is a sort of spiritual birth pang. The whole being is involved. There are physicians and psychologists who offer a synthetic medicinal substance to relieve one of this pang. But we must remember that, while man is partially mechanistic or biochemical, this does not by any means exhaust his being; he still retains something that can never be reached by medicine. This is where his spirituality lies, and it is kufu that finally wakes us to our spirituality."

Kufu is a source of imagination and creativity; to know how to master Kufu means to know how to educate students and engineers to be creative. However, Suzuki says that unfortunately no teaching and no methods can help to master the secrets of kufu, because technique is secondary in mastering kufu and each student and engineer must struggle to develop his or her own kufu from within. Once they have mastered their own kufu in engineering, they become masters of engineering. This is exactly why Professor Emori said in his famous book on scale modeling, "professional intuition is the best tool in engineering." Taiichi Ohno, one of the fathers of the Toyota Production System, reminds us that "If you look up the word 'engineer' in an English dictionary, you might find 'technologist,' while in Japanese, its meaning uses the character for 'art.'" A schematic showing characteristics of Eastern culture, on which professional intuition is based, is shown in **Figure 3**, compared to characteristics of Western culture on which scientific methods are based.

A skilled craftsman can design parts or fix problems based on his/her experience and professional intuition with scientific reasoning and understanding. His/her experience and know-how can help solve problems. Three scientific methods: theory, experiment and computation, can help us to understand why the craftsman's solution worked for a particular problem, but may not work for other problems. Here again, the craftsman's role is the same as the engineer's role in creation and problem solving, while a scientist's role is needed here to understand why the solution worked.

Both engineering and scientific functions are required when industry wants to develop an effective continuous improvement system. It would be beneficial for industry to have these two functions in its organization. However, the scientific function often finds difficulty in justifying itself to company budgets. On the other hand, the university can be an excellent source for the company's scientific function.

There are two types of university research: curiosity-driven basic research and purpose-driven applied research. R4D is a good example of applied research, as we discussed earlier. It would be short sighted, however, if university researchers only conducted R4D research by staying inside the boundary determined by a well focused R4D plan, and ignoring curiosity-driven basic research. History has proven that many inventions were made by looking at the same problem from a different point of view. A good balance between basic research and applied research, therefore, is clearly needed for a university researcher to effectively solve industrial problems. Successful university-industry collaboration on research is like growing a fruit tree; basic research is its roots, R4D is the branch to bear fruits, and interdependent relationship is the trunk.

Part two of this article will appear in the next issue of Energeia.

Kozo Saito is the Tennessee Valley Authority Professor in Mechanical Engineering at the University of Kentucky. His research interests are in Combustion, Fire Research, Painting Technology, Thermal Sensing and Control, Scale Modeling and Lean Manufacturing. He is also the Director of IAES – The Industrial Applications and Engineering Science Laboratory.

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Chemistry Professor on Sabbatical at CAER

The CAER is pleased to announce that Dr. Mark Meier, University of Kentucky Professor of Chemistry, will be a visiting scientist at the lab for one year. Mark has worked closely with our Carbon Materials Group for several years and this on-site sabbatical provides a greater opportunity to collaborate on a daily basis. His main research interests are in the chemistry of fullerenes and carbon nanotubes.

He has been a member of the university's faculty since 1990. Previous to that, he received a Ph.D. from the University of Oregon, which was followed by a Post-doctoral Fellowship at the University of Texas at Austin.

We welcome the opportunity to work with Mark and his students.

CAER Director to Take New Position with Ethanol Company

Director Ari Geertsema announced on June 26th that he plans to take a position in Denver, Colorado as Senior Vice President for Technology of a venture capital backed start-up company. The company will build decentralized biomass-to-ethanol facilities using gasification. He will continue to serve as CAER Director until September. Rodney Andrews, Associate Director of the CAER Carbon Group, will be the Acting Director while a search is conducted for a successor.

The Center for Applied Energy Research at the University of Kentucky is organizing a workshop to be held July 12 - 14, 2007, immediately preceding the international carbon conference, Carbon 2007. Next year marks the American Carbon Society's 50th anniversary.

WORKSHOP ON ADSORBENT CARBON APPLICATIONS

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Focus on Coal Safety

Bill Caylor
President, Kentucky Coal Association

Because the mining of coal has been an integral part of life in Kentucky for nearly two centuries, miners' injuries and/or losses of life in mine accidents have sadly also been woven into our Commonwealth's history.

Recent tragic events in mines in both West Virginia and Eastern Kentucky have once again focused the nation's attention on the inherent dangers associated with coal mining. From those events has come a public outcry for increased mine safety.

Our industry shares this concern for human lives, and we mourn the tragedies in our coal fields. And while we have certainly made dramatic progress in ensuring safety for mine workers over the past two decades, our industry goals are fewer injuries and zero fatalities. We're committed to achieving both. Why? Because coal mining is, at best, a difficult job. The men and women who mine coal usually make just over $50,000 a year, and they earn every penny of that money. Essentially, they work in the dark so we Kentuckians and millions of Americans don't have to. Our coal miners deserve our respect, our admiration, our thanks---and they deserve to be safe as they mine Kentucky's most abundant natural resource; a fossil fuel which provides 91% of our Commonwealth's electric power, and 52% of America's as well.

Thanks to modernization, coal mining today is far safer than it has ever been. Coal miners are safer from accidents than the average Kentucky worker. Accidents resulting in injuries are steadily declining, as are fatalities. Across Kentucky, during 1996-2002, the coal industry averaged 8.7 deaths per year, as compared to manufacturing's 16.7, construction's 19.2, agriculture/forestry/fishing 25, and transportation/public utilities 21.3. Our industry's "statistics" are lower, but they need to be even more so.

Because of recent mine disasters, we have seen the passage of mine safety legislation on both federal and state levels. Key mine safety law changes include:

- Emergency communications between the surface and the underground working section. While Kentucky requires wired communications, the federal legislation pushes for wireless communications and tracking devices for miners.
- Emergency action plans requiring more frequent training for mine evacuation.
- Mine equipment review panels to review new safety technologies.
- Storage of extra breathing devices, called Self Contained Self Rescuers ("SCSR"), at 30 minute travel time intervals.
- Lifeline cords in all designated escapeways with directional devices.
- Reporting of serious accidents within 15 minutes.

Kentucky legislation added provisions for increased fines, more mine inspections, and closed safety loopholes. Interestingly, Kentucky became the first state in the nation to require drug testing of coal miners.

Kentucky's new drug testing legislation includes the following provisions:

- Mandated reduction in workers' compensation premium for having a drug-free workplace program, including an employee assistance program.
- Drug testing before a miner can get a new certification.
- Annual retraining to include drug abuse education.
- Immediate reporting of miners who are fired for violation of a company's drug policy, who refuse to submit for a drug test, or who test positive and fail to complete an employee assistance program.
- Immediate suspension of the miner's certification for drug and alcohol violations.
- Mandated drug testing of serious accident victims and discretionary testing of those nearby who may have contributed to or witnessed the accident or fatality.

As an industry, Kentucky coal can, and will, do more. Together, we will continue to improve on safety. Together, we will continue to mine the coal which will provide cheap, dependable electricity for our state and our nation. We will continue to support clean coal technology, which reduces air pollutants from coal-fired plants. And, as we Americans continue to demand lower prices for gasoline, Kentucky coal can be a key in reducing America's obsession with foreign oil as our industry invests in technology that will convert our coal to liquid fuel, which can then be available "at the pump" for about $1.20 a gallon, plus taxes.

Kentucky Coal is proud to play many vital roles across our Commonwealth, including the generation of jobs, of tax dollars which support education, and of pride in an industry which has pledged itself to help protect its workers, while helping to fulfill America's growing energy needs.

The 2007 World of Coal Ash (WOCA)

Conference is organized by the **University of Kentucky's Center for Applied Energy Research (CAER) and the American Coal Ash Association (ACAA).** Drawing on the expertise of industry members, researchers, businesses, and government, the agenda contains four parallel sessions, at least one of which will accommodate each attendee's interests. Major topics addressed include, but are not limited to:

Synthetic Gypsum, Storage and Disposal, Concrete & Cement, Environmental Issues, Regulatory Issues, Emerging Technologies, Agriculture, Economics, Co-combustion, Fly Ash, Boiler Slag

Abstracts for oral and poster presentations are due **October 2, 2006**.
Abstract submission instructions are at:
www.worldofcoalash.org/presenters/callforpapers.html

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