INNOVATIVE DECISION-MAKING TECHNOLOGY FOR SUSTAINABLE COMPETITIVENESS OF US PRODUCTIVE ENTERPRISES

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Abstract

This paper argues that the Obama administration goal of reestablishing a sustainable US manufacturing industry requires a reversal of the current compartmentalization of enterprises; in particular, that production decisions include preservation of equipment as well as the environment. This will require decision-making technology different from what is available today.

The paper recommends that the TIP program support the development of new generations of decision-making technology that integrate production with equipment preservation and environmental stewardship. Benefits need to be demonstrated through trial implementations of prototypes in typical real-life industrial settings. Analyses should examine the effectiveness of the new technology and extrapolate to the improvement potential on a national scale.

Mandate for Increasing Productivity of the Manufacturing Sector

> *"Many communities hit hardest by job losses, those built around dying factories and mills, have been slowest to see relief from President Barack Obama's stimulus plan, underscoring how hard it is for Washington policymakers to create lasting work in areas that need it most[2]."*

In manufacturing and service delivery enterprises a number of factors have coalesced to emphasize short-term output and sales, even if that means depleting the productive capability in the long run. With today's mandate for sustainability, this practice is becoming increasingly unacceptable and impractical. Even if all external obstacles were removed, the typical enterprise would lack the decision-making technology to implement truly sustainable operations. Targeted research and development efforts are needed to identify the deficiencies of existing technology and to demonstrate viable alternatives.

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[2] New York Times AP Wire, November 1, 2009

In terms of overall improvement of industrial productivity, government has made it clear that it wants to make a contribution toward developing new approaches and technologies. According to the White House Office of Science and Technology Policy (OSTP):

"The Obama administration … is committed to advancing a comprehensive technology and innovation plan that will: …. Develop Next Generation Manufacturing Technologies: Create and install new manufacturing methods so America can again create its fair share of the products we use and to revitalize the domestic job market." [3]

More specifically, in a 2009 white paper, OSTP, found that:

"Despite [the] American economy's historic strength, our economic growth has rested for too long on an unstable foundation. Explosive growth in one sector of the economy has provided a shortterm boost while masking long-term weaknesses."

"A short-term view of the economy masks underinvestments in essential drivers of sustainable, broadly-shared growth. It promotes temporary fixes over lasting solutions."

"Our physical and technological infrastructure has been neglected, threatening the ability of American businesses to compete with the rest of the world."[4]

The short term nature of investor rewards and executive compensation, the narrow compartmentalization of enterprises into bonus pools, and a widespread practice of defining incentives in terms of output have led to an emphasis of output at the expense of preservation of the productive capacity and environmental resources. The resulting overall cost is higher than necessary. So is the damage to the environment. In the long term, manufacturing facilities are left to decay to the point where refurbishment is more expensive than building new plants at different locations. Left behind is blight in formerly prosperous centers of manufacturing, including the "rust-belt, and an enormous toll is exacted on the labor force, the regional economy, and the environment. The situation is aggravated by sophisticated logistics systems that make it possible to shift production globally to the facility that, at the time, offers it at the lowest price.

Success for American industry and restoration of American jobs in the global competition for markets and productivity is increasingly dependent on overall production efficiency. This is partly because labor cost has become a decreasing fraction of the overall cost. And the growing costs of mitigating climate change will tend to be shared worldwide, reducing its impact on the structure of competitiveness.

In the words of the OSTP,
"*The basis of competition and the nature of the economy have changed, and we must change with them. …, manufacturing and services have merged, knowledge is a key factor of production, and services we thought could only be provided in particular countries are available anywhere. We need new ideas to provide Americans with new jobs, new services*

[3] http://www.ostp.gov/cs/issues/technology
[4] "A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs," Executive Office of the President, National Economic Council, Office of Science and Technology Policy, 2009

that take advantage of our globally interconnected world, and new skills that improve our manufacturing capabilities."[5]

The Case of the Steel Industry

It is difficult to measure the damage to the economy as a whole from the emphasis on output versus sustainment of capacity in production enterprises. One sector where indications of the magnitude of the problem may be obtained fairly easily is the steel industry. The production process in a mill is much less complex than most production processes. It is fairly easy to isolate steps of this process and produce meaningful statements about their overall efficiency.

Developments in the steel industry have been particularly compelling. The slide of the industry over the last half century and the plight in which it has placed regions and the labor force have been well documented.[6] [7] [8]

Serrin observes how phenomenal it was that *"tens of thousands of men and women were losing their jobs. Many were in their forties and fifties, others in their sixties. Many would never find meaningful employment again. Industry after industry was in crisis – steel, mining, autos, rubber, textiles, the needle trades, and more. A whole way of life was disappearing as town after town, whole areas of America, were going down. What was more phenomenal was that no one seemed to care."*[9]

"… experts [journalists, stock analysts, economists] *in their glass offices for the most part did not have the slightest idea what was wrong with the steel industry."*[10]

Many factors are to blame for the demise of the industry, including: misguided corporate objectives, unsuitable organizational structures, antagonistic labor relations, rigid union rules, and excessive labor rates. Smith chronicles a case in which executive and boardroom-level decision-making has robbed a marginal steel mill of any chance of a turn–around, despite the willingness of labor to make significant concessions.[11]

According to Serrin, *"it was not macroeconomics – that is imports, trade policy, changing markets, and the like – that brought the steel industry down. It was, indeed, the small stuff that the experts had no knowledge of, that was going on in the plants, in the corporation, in the union. I suspect – I know – that these things are the basis not only for the upheaval in*

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[5] ibid
[6] John P. Hoerr, And the Wolf Finally Came, The Decline of the American Steel Industry, University of Pittsburgh Press, Pittsburgh, 1988
[7] Mark Reutter, Sparrows Point, Making Steel, The Rise and Ruin of American Industrial Might, Summit Books, New York, 1988
[8] William Serrin, Homestead, The Glory and Tragedy of an American Steel Town, Vintage Books, New York, 1993
[9] Ibid, page xix
[10] Ibid, page xxi
[11] Philip Hartley Smith, Board Betrayal, Failed Governance and Management Hand in Hand with Arthur Anderson, An ESOP Fable, Ladlesheet Press, Pittsburgh 2003

the steel industry but, as the layoffs and economic changes of the 1980's continued into the 1990's, for the upheaval in most of our troubled industries and in the other troubled institutions of American life."

"A strange way to run a country, I thought – use things up, people and places, and throw them away… Homestead and the other places were yesterday and today; more Homesteads will come tomorrow."[12]

A relatively simple example of the burden that lack of attention to the condition of equipment can impose on the well-being of a steel plant, the national economy, and the environment can be found in reheat furnaces. In a modern steel mill, these furnaces are positioned between the continuous caster and the rolling mill to reheat the steel, homogenize the temperature distribution in it, or simply hold and transport it. The furnace is operated continuously by three shifts a day, with each shift responsible for and rewarded for the output it achieves.

In the USA, most, if not all, steel reheated for re-rolling into coil or shapes passes through a reheat furnace. A well-designed reheat furnace of the walking beam, walking hearth, or pusher type that is in good operating condition will achieve a fuel rate of around 1.2×10^6 Btu per ton heated. When in deteriorated condition due to poor maintenance, the same type of furnace will burn fuel at a rate in excess of 1.4×10^6 Btu per ton. For reheat furnaces of the tunnel type, the fuel rates are, respectively, 400,000 and 500,000Btu per ton heated.

The annual steel production of the USA is between 90 and 110 million tons per year. Assuming the low end of this range, the production is split into about 78 million tons reheated through the walking beam, walking hearth, and pusher furnaces, and 12 million ton through tunnel furnaces. The differences in fuel rates amount to an excess fuel consumption of 15.6×10^{12} Btu per year for the walking beam, walking hearth, or pusher type furnaces, and 1.2×10^{12} Btu per year for the tunnel furnaces, for a total of 16.8×10^{12} Btu per year. At an estimated cost of \$10 per 10^6 Btu, this represents potential savings through better attention to the operating condition of the furnaces of \$168,000,000 per year.

Since virtually all of these furnaces use natural gas, the potential reduction of environmental burden amounts to 29 lb and 14.5 lb, respectively, of CO_2 per ton of steel heated. At the national level this amounts to 2.4×10^9 lb CO_2 per year. Additionally, emissions of NO_x, waste water, and other pollutants, and electricity consumption will decrease proportionally. Finally, furnaces operating in improved condition will produce an increase in product quality and safety, and positively affect numerous other factors.[13]

In the other manufacturing industries the production processes are much more intertwined, and it is more difficult both to isolate individual stations and determine their relative efficiencies and also to calculate the impact of poor equipment condition on productivity. However, a recent review of operating practices in metal-cutting manufacturing plants[14]

[12] Serrin, 1993, page xiv
[13] Source: Bricmont Inc., Canonsburg, PA
[14] Maximilian M. Etschmaier, Condition Based Maintenance for Smart Machines, Task 1: Preliminary Review, unpublished project report, NIST Manufacturing Engineering Laboratory, December 2006

shows that concern for the condition of a machine tool is almost universally subordinated to the mandate to meet short-term production goals. The review also produced considerable anecdotal evidence that management frequently accepts the possibility of significant damage in return for short-term continuation of machine availability for production.

In public transit systems there is an additional disincentive to including sustainability of equipment in operational decision-making: the federal government contributes a substantial portion of the capital cost, but not of the operating and maintenance cost. As a consequence, even as transit buses are routinely retired at a very early age, they still often fail at an astounding rate of well below 10,000 miles between "road calls" in revenue service operations.[15] [16]

Even if data on the improvement potential for all industries are difficult to come by, the three examples show that depletion of the capacity of productive equipment at the expense of short-term output gains is a costly practice that inflicts severe penalties on the long-term competitiveness of our nation's industry and infrastructure.

The Need for Government-Sponsored Research and Demonstration

It will be difficult to reverse the trend toward short-term and myopic reward systems. However, even as changes in laws and regulations begin to have an impact, a large investment in matching decision-making technology infrastructure will be required to sustain the impact. The capabilities of this technology will be different from what is available today. Given the uncertainty that the trend toward short-term reward systems can actually be reversed, it can not be expected that private investment alone can assure that this technology will be available when needed.

This then would be the right time for a government initiative to stimulate and support exploration of alternative approaches to decision-making technology for the operation of productive enterprises. These new approaches would consider the long-term survivability of enterprises as well as the sustainability of the planet.

Etschmaier[17] shows that undistorted stewardship of the environment requires transparent accounting of burdens that are imposed on it at the level of elemental activities. The proposed "Burden Added Tax" provides a rational structure for assessing cost at a national level. Similar accounting of the burden can be imposed on the use of productive equipment. However, employing existing methods and technologies to use these data in an optimization of operations in a productive enterprise will lead to formulations of prohibitive complexity and size. Additionally, events that are essentially random will render results all

[15] Maximilian M. Etschmaier, Transit Bus Maintenance in the United States, Transportation Research-A, Vol. 19A No1, pp 1-14, 1985

[16] Informal updates by author from FTA statistics and Transit Company statistics (FTA no longer publishes road call rates)

[17] Maximilian M. Etschmaier, Environmental Policy and Regulation, and the Practice of Management: A Call for a Burden Added Tax, International Journal of Environmental, Cultural, Economic and Social Sustainability, 2005

but meaningless. Instead, it will be necessary to develop new model structures and new technologies for decision-making that can handle the full complexity of the problem, yet without requiring inordinate resources or training for implementation. Strategies for deployment will need to be crafted so that the complexity of the technology will not produce costs in excess of the benefit or fall outside the envelope of skills that can reasonably be expected to be available in a production environment.

Exploration of alternative structures and technologies will be required to identify the best approach. Contrary to other technology programs, however, it is necessary to directly address the problem in its entirety, rather than to study isolated sub-problems.
It is recommended that the TIP program support the development of prototype systems of new approaches to an overall optimization of productive operations. The practicality and viability of these prototypes should be demonstrated in a trial implementation in a typical real-life industrial setting. The trial implementation should be designed to reliably assess the improvement provided by the system over existing systems. Analysis of the performance should be conducted to extrapolate from the trial implementation to improvement potentials on a national scale.

The results of this work will lead to significant improvements of productivity and competitiveness at the national level. It will also lay a foundation for continued leadership of the nation in software products for the management of industrial operations. While the benefits of this effort are difficult to estimate with any degree of accuracy, the numbers presented on steel reheat furnaces suggest that the improvements should be worth many billions per year. This is compounded by the significant reduction in the environmental burden that can be achieved. The proposed work, combined with the regulatory and legislative measures the administration is contemplating, will lead to increased long-term stability of regional economies and labor markets. It will help restore a highly productive industrial labor force that can once again be the envy of the world.

At the present time there is little push for the development of the management technology advocated here. Hoop and Spearman[18] argue that *"The reductionist framework established by scientific management is behind the traditional emphasis by the industrial engineers on line balancing and machine utilization. It is also at the root of the decades-long fascination of operations researchers with simplistic scheduling problems, an obsession that produced 30 years of literature and virtually no applications (Dudek, Panwalker, and Smith 1992[19]). The flaw in these approaches is not the analytic techniques themselves, but the lack of an objective that is consistent with the overall system objective."*

"The real lesson … is that there is no easy solution. We Americans have a resolute faith in a swift and permanent resolution of the manufacturing problem. … Each successive approach to manufacturing management – scientific management, operations research, MRP, JIT, TQM, BPR, ERP, etc. – has been sold as the solution. Each one has

[18] Wallace J. Hoop and Mark L. Spearman, Factory Physics, Foundation of Manufacturing Management, Second Edition, Irwin McGraw Hill, New York 2001, page 31
[19] Dudek, Panwalker, and Smith, The Lessons of Flow-Shop Research, Operations Research Vol. 40, Number 1, 1992

disappointed us, but we continue to look for the elusive 'technological silver bullet' to save American Manufacturing."[20]

Because of existing organizational structures, there is also no place for the development of a new type of decision-making technology in current enterprises. As government is trying to create more efficient structures for industry, it needs to make sure that when those structures come to bear, the technology infrastructure will be available so that their full benefit can be realized.

Private enterprises currently have little incentive to develop this new technology. If government will not promote it now, the technology will not be available when needed, and industry will gradually revert back to old patterns of unrealized potential and limited competitiveness.

Conclusion

It is recommended that the TIP program support the development of innovative types of decision-making technology that will include sustainment of physical assets and mitigation of the impact on the environment while optimizing production. The practicality and viability of this technology should be demonstrated through the development of a prototype system, including trial implementation in typical real-life industrial settings. The trial implementations should be designed to permit reliable extrapolation of the results to the improvement potential on a national scale.

The proposed research will lead to significant gains in labor productivity and competitiveness. Combined with the regulatory and legislative measures the Obama Administration is contemplating, this will translate into significant gains at the national level and result in greater long-term stability in regional economies and labor markets.

The results of the proposed research will also help put the US into a position of leadership in climate change mitigation and environmental stewardship. It will lay a foundation for the nation's continued leadership in software products for the management of industrial operations.

[20] Hoop and Spearman, 2001, page 182