NATIONAL MANUFACTURING COMPETITIVENESS: ADVANCED RESEARCH AND SIMULATION FOR SUSTAINABLE COMPETITIVE ADVANTAGE

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Executive Summary

A Critical National Need

In the 1960s, American firms discovered the utility of outsourcing their manufacturing operations to Asia. In their avid pursuit of lower production costs, these firms began a trend possessing extensive implications for the American economy. If allowed to continue, these trends and their consequences represent a significant threat to future U.S. economic security. In order to sustain advantages in research and development, innovation, and technology and contribute to the economic growth of the country, it is critical for the U.S. to foster manufacturing competitiveness.

Magnitude of the Problem

Though the service economy has become a net exporter in the last decade, the manufacturing trade balance has rapidly declined, causing the loss of more than 3.5 million U.S. manufacturing jobs since 2000. The primary contributors to these losses were the cost of labor, energy, healthcare, and taxes, all of which reduced the competitiveness of U.S. manufacturers. Volatile fuel prices and the weakening U.S. dollar have also contributed to the severity of the problem, which will persist if unaddressed. According to Bureau of Labor Statistics estimates, manufacturing and goods-producing job losses will continue well into the next decade.[i]

Societal Challenges

Defined as issues confronted by society that, when not addressed, could negatively affect the overall function and quality of life of the nation, there are significant societal challenges within the manufacturing sector.[ii] Of these challenges, issues of supply chain management should be at the forefront. Dedicating new resources to address the sector's needs – such as accurate and accessible information, simulation tools, and advanced research – will enable the attraction, retention, and growth of manufacturing industries within the United States.

However, the benefits of performing research and simulations on supply chain cost structures, risk analysis, the true cost of logistics, taxes and duties, supplier and customer bases, labor costs, and workforce availability do not end with the manufacturing sector. Findings from these efforts will also be applicable to other industries and economic sectors, including systems involved in securing the nation's borders while simultaneously providing for the free flow of commerce.

Research into any number of supply-chain/logistics issues could significantly affect the manufacturing sector. However, to achieve transformative results that will have spillover effects on other industries and government functions, the main objectives of the research should be to develop an optimization framework for supply chain coordination where critical modeling information is private to facilities (e.g., suppliers, manufacturers, warehouses, and retailers) or coalitions of facilities. The research should focus on important inventory control decisions, such as when and how much to produce in manufacturing facilities, how much inventory to carry in raw materials and finished goods, and when and how much material to transfer between facilities such that, system-wide costs are minimized and given service levels are satisfied. This research objective will contribute to the understanding of the important and not well-understood problem of supply chain coordination under private information. It is expected that results of the proposed research will be applicable to other important operations research problems with similar characteristics appearing in health-care systems, homeland security, and other critical contexts.

Conclusions

Though it has been declining for several years, U.S. manufacturing is far from the point of no return. Given the country's capacity for technological innovation, its education infrastructure, and available workforce, there is significant potential for the return of lost jobs. For the areas hardest-hit by the departure of manufacturers, the return of full-time, sustainable and resilient employment opportunities will be a means to positively impact the lives of not only employees in new jobs, but also the lives of their families and the lives of those in their regions working in the service industry.

To achieve this future, research and simulations must be performed in order to provide the proper incentives and information to manufacturers. Beneficial for the firms themselves, such actions also improve the probability of organizations choosing to bring their manufacturing operations to the United States. An additional benefit of these efforts will be the attraction of foreign and domestic capital investment in U.S. manufacturing.

The spillover effects of these research efforts will be broad and will have applicability in industries from healthcare to transportation. Further, findings could also be used to improve the relationship between security and commerce at border crossings, facilitating new techniques and technologies for the protection of our homeland's physical and economic security.

NATIONAL MANUFACTURING COMPETITIVENESS: ADVANCED RESEARCH AND SIMULATION FOR SUSTAINABLE COMPETITIVE ADVANTAGE

A Critical National Need

In the 1960s, American firms discovered the utility of outsourcing their manufacturing operations to Asia. In their avid pursuit of lower production costs, these firms began a trend possessing extensive implications for the American economy. When this trend first began, manufacturing accounted for approximately 53 percent of the U.S. Gross Domestic Product; at present, this percentage has plummeted to less than 12.[iii] Further, the U.S. trade deficit in goods has ballooned more than $600 billion during the last ten years, now surpassing the $800 billion mark.[iv] If allowed to continue, these trends and their consequences will possess significant ramifications for the stability of the U.S. economy and therefore represent a threat to the nation's economic security.

Changing this trend will require action. In 2007, the Bureau of Labor Statistics projected a further loss of 732,000 jobs in the U.S. goods-producing sector by 2016. Given this, it is presently a critical need for the U.S. to foster manufacturing competitiveness in order to be able to sustain advantages in research and development, innovation, and technology and thereby contribute to economic growth of the country.

Magnitude of the Problem

Although the U.S.' service economy has grown into a net exporter in the past decade, the rapid decline of the manufacturing trade balance has created significant consequences. Foremost among these is the loss of more than 3.5 million U.S. manufacturing jobs since 2000. The competitiveness of U.S. manufacturers was reduced during these time frames due primarily to the costs of labor, energy, healthcare, and taxes. Additionally, rapidly rising fuel prices and the weakening U.S. dollar contributed significantly to the severity of the problem.

These massive job losses were felt throughout the nation. The Great Lakes states were particularly hard hit, losing approximately 1.125 million jobs between 1995-2005.[v] The State of Texas lost more than 10,000 manufacturing jobs last year, decreasing that sector's overall contribution to Texas' economy from 8.9 percent to 8.6 percent.[vi] Nationally, the remaining 14,197,300 manufacturing jobs in the United States represented 9.4 percent of the overall U.S. workforce in 2006, a decrease from its 12.8 percent level in 1996.[vii]

These losses affect more than just the manufacturing sector. Spillover effects from the sector's decline have been felt not only by its employees and their families, but also by nearly every other sector. Without the tax revenues from manufacturing plants and their employees, governments at every level see their overall revenues reduced. Service industry businesses in the regions where major reductions occur are negatively affected due to the decrease of their customer base. In

sum, the total economic development of a region – such as the Rust Belt – can decline based upon the decline of the manufacturing sector, as the closings dissuade new business creation and the attraction of major industry.

Societal Challenges

Defined as issues confronted by society that, when not addressed, could negatively affect the overall function and quality of life of the nation, there are significant societal challenges arising from within the manufacturing sector.[viii] Of these challenges, issues of supply chain management should be at the forefront. Dedicating new resources to address the sector's needs –such as accurate and accessible information, simulation tools, and advanced research— will enable the attraction, retention, and growth of manufacturing industries within the United States.

However, the benefits of performing research and simulations on supply chain cost structures, risk analysis, the true cost of logistics, taxes and duties, supplier and customer bases, labor costs, and workforce availability do not end with the manufacturing sector. Findings from these efforts will also be applicable to other industries and economic sectors, including healthcare and systems involved in securing the nation's borders while simultaneously providing for the more efficient flow of commerce. Two years prior to the September 11 attacks and three years prior to the creation of the Department of Homeland Security, several comprehensive studies estimated that in 1999, $77.4 million was lost due to inefficiencies at border crossings.[ix] These inefficiencies can be addressed with research efforts in supply chain management, the results of which will provide an alternative to devise robust and more scalable distributed algorithms that require minimal information flows between sub-problems.

Gaining manufacturing competitiveness is essential for sustainable growth in the U.S. economy, but what is manufacturing? There is a common misconception that only steel, automotive, and machinery industries are included in this sector. However, nanotechnology, lasers, robotics, biotechnology, healthcare, and other advanced manufacturing markets are also part of the new manufacturing economy and, as such, it is necessary to include these in any conversation about improving the state of U.S. manufacturing capabilities. This need is particularly relevant when considering which industries to include in the study of streamlining the flow of commerce through optimized systems for supply chain management.

Supply Chain Management

Supply networks in today's highly competitive and time-sensitive business environments are dynamic systems where national and international alliances among companies are continuously redefined to rapidly satisfy global market needs. Although a full information exchange is technically feasible, often the participants in the supply chain will be reluctant to freely share private information (e.g. costs and production capacity), and let a third omnipotent party dictate their inventory policies. This phenomenon is often observed when competitors constitute the same supply-chain; an example appears in the automotive industry where a single firm (e.g. TRW) supplies air-bags and steering wheel subassemblies to competing manufacturers in the U.S. and Mexico (including Ford, GM, Nissan, Honda, and Volkswagen). Another example occurs in the semiconductor industry where competitor companies (e.g. Intel and AMD; Cisco and Alcatel; Sony and Panasonic) use the same contractor (e.g. Amkor Technologies) to

assemble and test their semiconductor devices. We conjecture that the co-existence of competitors and the increasing presence of private information in the same global supply network will continue to grow in the future.

The pervasiveness of restricted information sharing in supply chains poses a monumental challenge to most existing approaches for global coordination. A new approach in the research efforts for this issue must be that it explicitly considers restricted information sharing in addition to the complexities resulting from the inherent system uncertainties such as demand, production, and transportation, and the interdependencies among the inventory, production, and distribution systems within and among participating members. The resulting problem is a complex large-scale stochastic optimization problem that, forced by the partition of information due to privacy requirements, must be collaboratively solved by multiple decision entities. A central research question is, *Can global coordination be achieved without a dominant central decision entity that has access to all necessary information and decisions?* If feasible, then the resulting benefits are not limited to solving an important class of large scale optimization problems, but also an alternative to devise robust and more scalable distributed algorithms that require minimal information flows between sub-problems. The global coordination of supply chains under private information is possible and will devise new efficient methodologies to solve related inventory and production decisions, and will discover stability and convergence conditions for this type of systems.

Optimization of large scale systems where the information is fractioned among several decision entities is an important type of problem that is not well understood. Investment is needed in order to consider complex systems that cannot be conveniently modeled using mathematics alone, and that, required by the forced partition of information, must be collaboratively solved by multiple decision entities. Finding a solution to the resulting complex and large-scale problem requires new hybrid methodologies that integrate state-of-the-art methods from optimization under partitioned information, stochastic programming, simulation optimization, and fuzzy mathematical programming. The strength of each approach is used in the solution methodology:

- Optimization under private information provides the framework for global optimization through the interaction of the participating decision makers while safeguarding their private information
- Stochastic programming is used to solve components of the problem that have suitable mathematical structure
- Fuzzy programming provides an alternative to deal with situations where the uncertain information is not well defined, or fuzzy
- Simulation optimization enables dealing with ill-structured problems or problems that are difficult to manipulate mathematically.

The resulting hybrid methodologies will have good performance, be robust, and be computationally efficient. However, most importantly, these methods will result in sound, logic-based decision support and supply chain optimization tools with the potential to foster competitiveness in the U.S. manufacturing sectors.

Regional Manufacturing

To date, globalization has been largely driven by western firms outsourcing their manufacturing to Asia. While the process has considerable growth opportunities remaining, the long term viability of shipping products across the Pacific Ocean is questionable given the high logistics costs and rising wages in Asian markets. Unfortunately, most companies do not consider all costs and factors when moving manufacturing to other countries or outsourcing from them. Providing research findings, data, tools and support will enable these organizations to make more informed decisions. Given that the long term viability of shipping products across the Pacific Ocean is questionable given the high logistics costs and rising wages in Asian markets, the opportunities to form regional manufacturing areas in the U.S. should be explored further. With the concept of regional manufacturing gaining strength across the world, there exists an opportunity for the formation of industry clusters specializing in manufacturing, services, and workforce development to suit the needs of specific industries.

This regional manufacturing concept is already well established, as many industrial centers tend to begin with a particular industry theme. Northern Italy focused on products manufactured by artisans and fashion industries centered on Milan. The area around the Bohai Gulf in China is another powerful region. In the U.S., the Detroit area was the first major region for automobile manufacture and, more recently, the Carolinas have seen a burst of activity.

In terms of total trade dollars between countries, China's purchases from the U.S. account for less than 15 percent of the trade between the two countries. However, Mexican purchases represent 35 percent of its U.S. trade. Given that the latter relationship is far more mature, and given that, as wealth increases in Mexico and their exports to the rest of the world continue to increase, the imbalance will likely tilt more in favor of the U.S. Southern California and Arizona have seen a boom in manufacturing activity with firms that support Mexican Maquilas or firms that serve as the next level of manufacturing in the U.S. If marketed correctly, the region could also attract other industries. As the Asian markets lose manufacturing back to the regional powerhouses, Northeast Mexico and Texas stand to benefit tremendously. Chinese and other Asian manufacturers have taken notice and started opening facilities in Mexico as well. These new facilities are not solely oriented to U.S. trade; many are directed at Mexico and will require materials from American firms.

An excellent real-world example of regional manufacturing can be found in the decision by Toyota to build a facility in San Antonio, Texas, basing its operation in one of the primary markets for the goods it produces. Though this facility only brought with it 2,000 jobs within the factory itself, the Texas Comptroller's Office forecast in Spring 2004 that the plant would bring a total of 16,000 new jobs, 12,000 of which would be permanent and more than 7,000 would be in Bexar County.[x]

This regional manufacturing concept needs numerous types of support to grow and succeed. Specifically, this support should consist of state and local governments acting to establish infrastructure, logistic providers deploying resources (such as warehousing and transportation), and the federal government streamlining cross border trade. But significant research efforts and

the effective implementation of findings are needed to accomplish this goal and realize its objectives.

Mapping to National Objectives

In light of the credit crisis which gripped the country earlier this year and the resulting aftershocks throughout the economy and financial markets, the need for a stable, steady source of economic strength for the United States is self-evident. However, given the service-dominated nature of the national economy, significant research, innovation and technology efforts will be required to re-invigorate the manufacturing sector in order for it to serve as a stabilizing force that will assist in increasing the overall resilience of U.S. economic security.

Meeting Timely Needs Not Met by Others

The broad role of the manufacturing sector in the U.S. economy is not traditionally emphasized in the news media. Even though the troubles of the country's Big Three automakers—Ford, General Motors, and Chrysler—have recently been publicized, this attention only came during the wider context of the financial crisis and the associated federal rescue plans for specific institutions. However, what has been attempted to date has failed to reverse the trend of staggering job losses and the overall decline of the U.S. manufacturing sector. As such, it is demonstrably clear that these efforts have not sufficed and that a new infusion of innovation, research and technology is required.

Research into any number of supply-chain/logistics issues could significantly affect the manufacturing sector. However, to achieve transformative results that will have spillover effects on other industries and government functions, the main objectives of the research should be to develop an optimization framework for supply chain coordination where critical modeling information is private to facilities (e.g., suppliers, manufacturers, warehouses, and retailers) or coalitions of facilities. The research should focus on important inventory control decisions, such as when and how much to produce in manufacturing facilities, how much inventory to carry in raw materials and finished goods, and when and how much material to transfer between facilities such that system-wide costs are minimized and given service levels are satisfied. This research objective will contribute to the understanding of the important and not well-understood problem of supply chain coordination under private information. It is expected that results of the proposed research will be applicable to other important operations research problems with similar characteristics appearing in health-care systems, homeland security, and other critical contexts.

Additional objectives should be to develop hybrid methodologies to solve large-scale stochastic optimization problems where the problem is decomposed *a-priori* due to a predetermined partition of modeling information among different decision entities rather than for mathematical convenience. Research in this area must address very complex systems that cannot be conveniently modeled using mathematics alone; in particular, research is required to integrate state-of-the-art methods from optimization under partitioned information (Opt-PI), stochastic programming (SP), simulation optimization (Sim-Opt), and fuzzy mathematical programming (FP).

Finally, research on Critical Success Factors (CSF) as well as solutions for 'Global Supply Chain Throughput' to make the U.S. a preferred manufacturing destination of the future is necessary. To enable the regional manufacturing models noted above and to rejuvenate the U.S. manufacturing sector, a compelling marketing narrative for why the U.S. is the place to establish manufacturing operations and to ship products through must be constructed. An important aspect of this initiative will be the emphasis of innovative, technology-based decision support systems that protect industry's proprietary data while offering valuable optimization technologies. However, for these systems to come into existence, research and simulation efforts must be supported.

Conclusion

Though it has been declining for several years, U.S. manufacturing is far from the point of no return. Given the country's capacity for technological innovation, its education infrastructure, and available workforce, there is significant potential for the return of lost jobs. For the areas hardest-hit by the departure of manufacturers, the return of full-time, sustainable and resilient employment opportunities will be a means to positively impact the lives of not only employees in new jobs, but also the lives of their families and the lives of those in their regions working in the service industry.

To achieve this future, research and simulations must be performed in order to provide the proper incentives and information to manufacturers. Making improved economic intelligence on aspects such as histories, workforce characteristics, logistics, and infrastructure capabilities will enable firms to avoid significant hidden costs but also, when coordinated with improved and coordinated marketing messages for U.S. manufacturing, may entice them to bring their manufacturing operations to the United States.

These efforts will impact more than just the manufacturing sector. Innovations in manufacturing and logistics technologies will be applicable to areas such as healthcare, transportation, and homeland security. The implications of these applications may bring new efficiencies to these areas, improving the efficacy of the nation's healthcare systems, advancing the interaction between security and commerce at our ports, and strengthening the work of the distribution systems for goods.

Finally, perhaps the greatest potential benefit of research efforts into supply chain management issues is attracting capital investment into this sector. Whether foreign or domestic, capital injections into the U.S. economy spur job creation, increase the strength of financial markets, and oftentimes initiate or speed economic development cycles. If this investment is made alongside the findings of the research and simulations for supply chain management and a push toward regional manufacturing, the potential to slow and eventually reverse the negative trends within the U.S. manufacturing sector will be significant and should not be discounted.

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[i] Bureau of Labor Statistics, http://www.bls.gov/opub/mlr/2007/11/art4full.pdf

[ii] TIP Sample White Paper, "Advanced Sensing Technologies for the Infrastructure: Roads, Highways, Bridges and Water"

[iii] The Little Blue Book of Big Trade Problems, Alliance for American Manufacturing, http://www.americanmanufacturing.org/wordpress/wp-content/uploads/2008/07/84457-littlebluebook.pdf

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