Current State of Advanced Manufacturing in the USA
Challenges and Recommendations for Improvement

(Literature Review)

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Abstract

The purpose of this literature review is to outline the current stage of advanced manufacturing and high-tech industries in the U.S. and Indiana as well to attempt to summarize the common challenges and recommendations for improvement in those fields. This article is organized as a summary from official and government web sources, such as the U.S. Department of Labor, Bureau of Labor and Statistics, National Science and Technology Council (NSTC) and The White House press releases. A significant part of the present report is devoted to the recent Obama's initiatives about reviving advanced manufacturing in America.

Definition of Advanced Manufacturing

In February 2012 , the Executive Office of the President and the National Science and Technology Council (NSTC) presented a document called *A National Strategic Plan for Advanced Manufacturing* [1], where Advanced Manufacturing (AM) was defined as a family of activities that (a) depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or (b) make use of cutting edge materials and emerging capabilities enabled by the physical and biological sciences, for example nanotechnology, chemistry, and biology. It involves both new ways to manufacture existing products, and the manufacture of new products emerging from new advanced technologies.

In general, advanced manufacturing can be divided under two sub-categories: "very high-technology industries", which employ great percentage of scientists and highly educated engineers, and "moderately high-technologies". Referring to the Bureau of Labor Statistics, economist Daniel Hecker[2] defines very high-technology industries as those in which science and engineering occupations account for at least five times their economy-wide percentage of employment. Moderately high-technology industries were defined as those in which science and engineering workers account for at least two but less than five times their economy-wide employment percentage.

Table 1. *High Technology Industries*[3]

High-Technology Category	Industry	Percent of industry employment in science and engineering occupations
Very High Technology*	Computer and Electronic Product Manufacturing	37.4%
	Pharmaceutical & Medicine Manufacturing	32.2
	Aerospace Product and Parts Manufacturing	31.0
Moderately High Technology**	Petroleum & Coal Products Manufacturing	14.6
	Chemical Manufacturing other than Pharmaceuticals & Medicines	12.8
	Transportation Equipment Manufacturing other than Motor Vehicles & Parts and Aerospace	12.7
	Machinery Manufacturing	12.6
	Electrical Equipment, Appliance, and Component Manufacturing	12.3

**Science and engineering occupations as percent of total industry employment are at least five times the national average.*

***Science and engineering occupations as percent of total industry employment are at least two but no more than five times the national average.*

Source: Authors' analysis of Bureau of Labor Statistics Occupational Employment Statistics survey data for 2010

Current State and Structure of Advanced Manufacturing in the USA

The NSTC National Strategic Plan[1] states that American manufacturing consists of six "anchor" industries, which are:

- computers and electronics,
- transportation equipment, including aerospace and motor vehicles/parts,
- low-wage manufacturing industries that combines textile mills, apparel, leather, wood, and furniture;
- chemicals,
- machinery,
- food industry.

Advanced Manufacturing in the USA is highly differentiated geographically. A majority of high-tech industries are formed in economic clusters located in (or around) metropolitan areas. These industrial clusters often consist of Small and Medium size Enterprises, where SMEs are defined as firms with fewer than 500 employees. According to the Census Bureau, they comprise 86% of all manufacturing establishments and employ 41% of the U.S. manufacturing workforce. Different regions of the country contrast greatly in their manufacturing industries, wages, tax- climate, and technology levels. In 2010, metropolitan areas were home to 79.5 % of manufacturing jobs. Figure 1 presents percentage of manufacturing jobs by region in 2010[4].

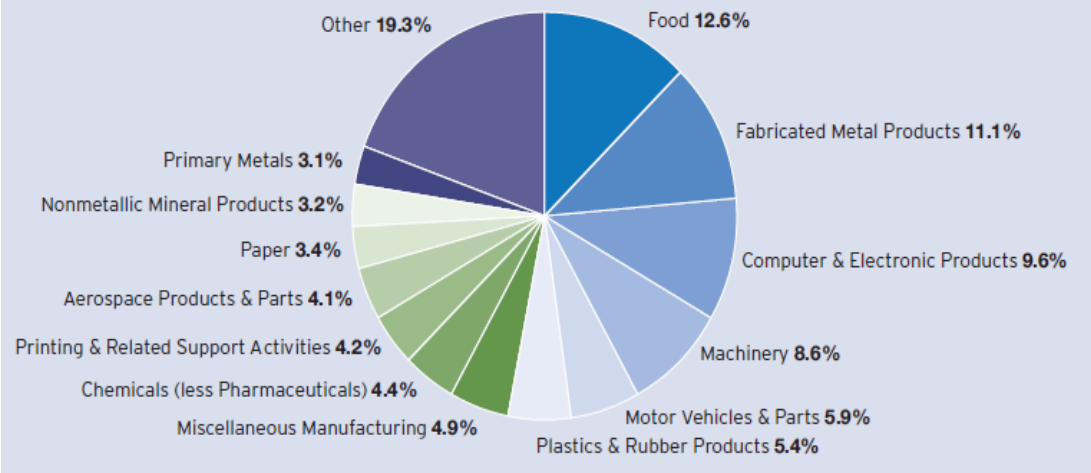

Figure 1. Industry Composition of Manufacturing Jobs, 2010[3].

U.S. manufacturers produced about $1.7 trillion of goods in 2010, about 11.7% of the U.S. gross domestic product (GDP). They employed 11.5 million Americans in jobs that paid on average about 21% more than average hourly compensation in private-sector service industries[5] .

Manufacturing in the U.S. has a larger multiplier effect compared to any other major economic activity. According to the Bureau of Economic Analysis, a dollar spent in manufacturing drives an additional $1.35 in economic activity[6]. Figure 2 presents percentage of High-Tech Manufacturing Jobs by region in 2010.

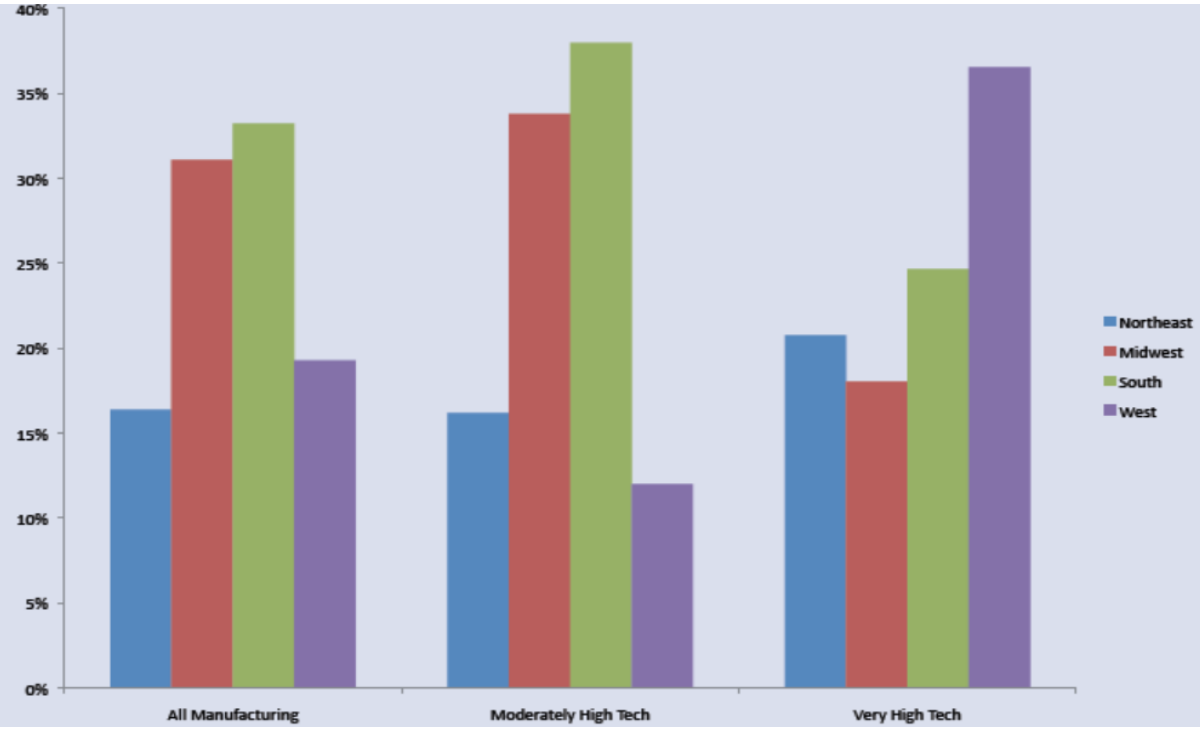

Figure 2. Percentage of Very High-Technology, Moderately High-Technology and All Manufacturing Jobs by Regions in 2010[4].

Manufacturing wages, are different depending on geographical location and industrial cluster. For example, average manufacturing earnings in San Jose, CA is almost $145,000 per year, were more than four times those in McAllen, TX where they were nearly $35,000. Although cost of living impacts significantly on pays, the numbers above show broad spectrum for qualified high –tech wages depending on geographical location. In metropolitan areas with the highest manufacturing wages, average earnings exceeded 150 percent for non-metropolitan regions in 2012[3].

At the present time, one of the biggest nationwide challenges comes from the decreasing of domestic jobs and moving manufacturing oversees. According to the Bureau of Labor Statistics, the number of manufacturing occupations declined by 40.7 % from 1979 (when it peaked at 19.4 million) through 2010. This reduction did not happen steadily over time; there were continues job loss from 1979 through 1990. The large wave occurred from 2000 through 2010 with the slow recovery in 2011. Between 2000 and 2010 the US lost 5.9 million manufacturing jobs, a decline of 33.8 %. In 2010 the United States had 11.5 million manufacturing jobs, which are equal to 8.5% of all U.S. jobs[11].

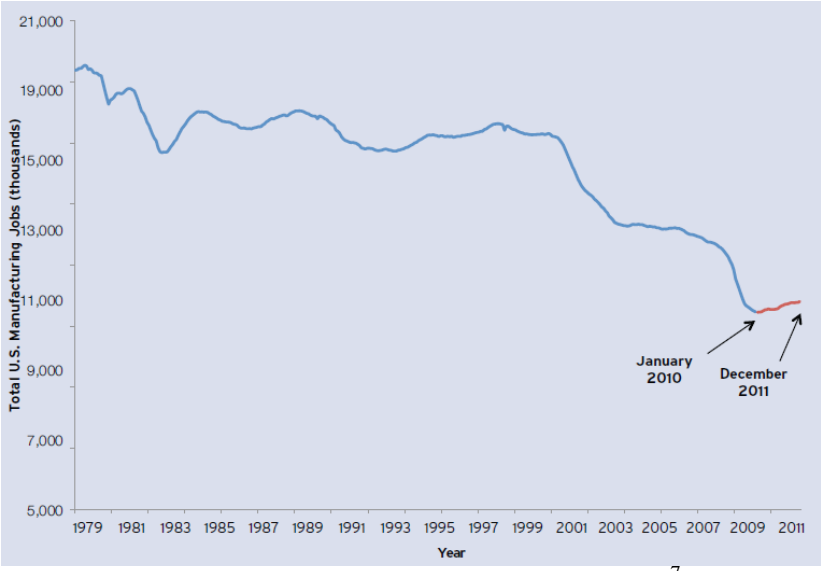

Figure 3. Manufacturing Jobs 1979-2011[7]

According to the *National strategic Plan for Advanced Manufacturing*, loss of jobs is a consequence of manufacturing capability gaps, which lead to the loss of substantial economic benefits and affects national security. Now the majority of industrial production (including computer parts and electronic devices) is done in Asia and Europe. The Figure 4 presents the trade balances in the high-technology goods for selected countries in the period of 1995-2008.

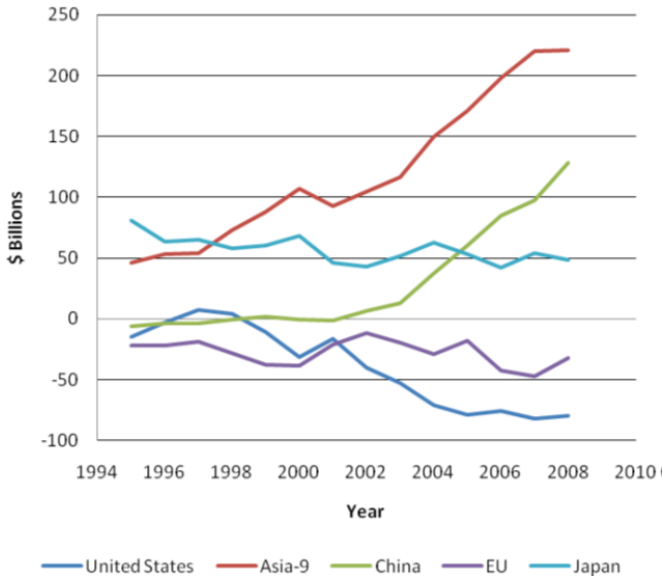

Figure 4. Trade Balance in High-Technology Goods for Selected Regions/Countries[9].

According to Census Bureau (Figure 5) there is a rapid decline in the U.S. trade balance for Advanced Technology Products.

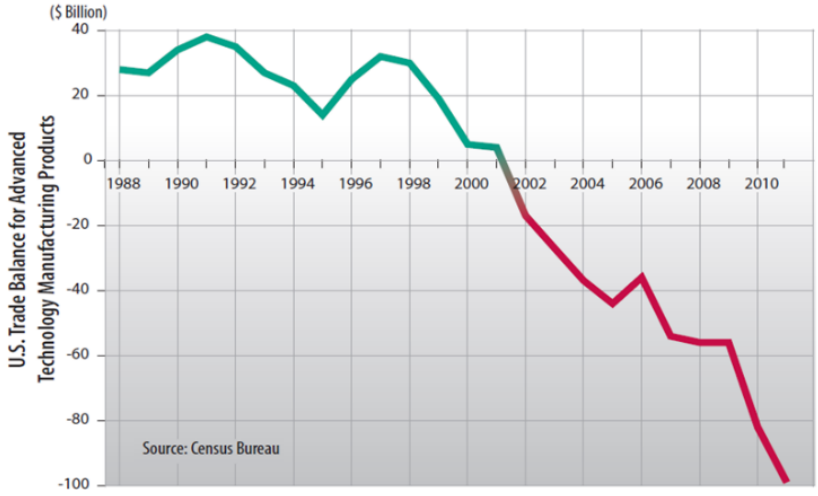

Figure 5. U.S. Trade Balance for Advanced Technology Products.

The Defense Production Act Committee (DPAC)[8] identified a number of vital government needs that the United States is currently unable to meet via secure and reliable domestic production.

> *DPAC analysis revealed several key technologies for which an impending lack of U.S. production will likely create national security vulnerabilities. Those include: aircraft landing gear, railcar components, large rotor disks for turbines, rocket engine parts, missile launch systems, unmanned aerial and ground vehicles, nuclear power components; aircraft fuselages; orbital vehicles; network routing and switching; optical data transport; advanced power electronics; low cost composites; and transmission conductors*[1].

Manufacturing in Indiana

According to Milken Institute, there is a group of eight industrial states where manufacturing plays a major economic role. Those states include California, Arizona, Indiana, Kansas, Minnesota, Oregon, Texas, and Washington. All those states have different tax-climate, wages, and industrial clusters on their territories. Traditionally California was recognized as a Global leader and the most technologically innovative state, in particular, because of the high-capacity, production and high profit of semiconductor and electronics industries in the region. Although, during a few last years, this state has been progressively losing more of its manufacturing employment, particularly high-value-added manufacturing, to other states such as Oregon, Texas, Minnesota, Washington, and Indiana[15]. California has seen its share of U.S. high-tech manufacturing and non-high-tech manufacturing jobs shrink, coming in last in job creation among the peer states. Indiana, on the other hand, has the most growth of 22% in its share of U.S. high-tech manufacturing employment even though its economy only grew by 7 % [10].

Manufacturing plays a vital role in the growth of Indiana's economy. Key Companies include such as: Eli Lilly and Company, Republic Airways Holdings Inc., Wellpoint, Steel Dynamics, Cummins, and Nisource. Figure 6 demonstrates top ten Indiana manufacturing sectors.

Milken Institute reports that Indiana's manufacturing real Gross State Product (GSP) totaled $58.5 billion or 28.2 % of the state's real GSP in 2007. Although, manufacturers' capital expenditures declined more than the U.S. average. This shows that in the period of 2000-2007 Indiana manufacturers have reduced their investments in the expansion and upgrades of their plants and equipment [10]. For 2012, the situation had been changed.

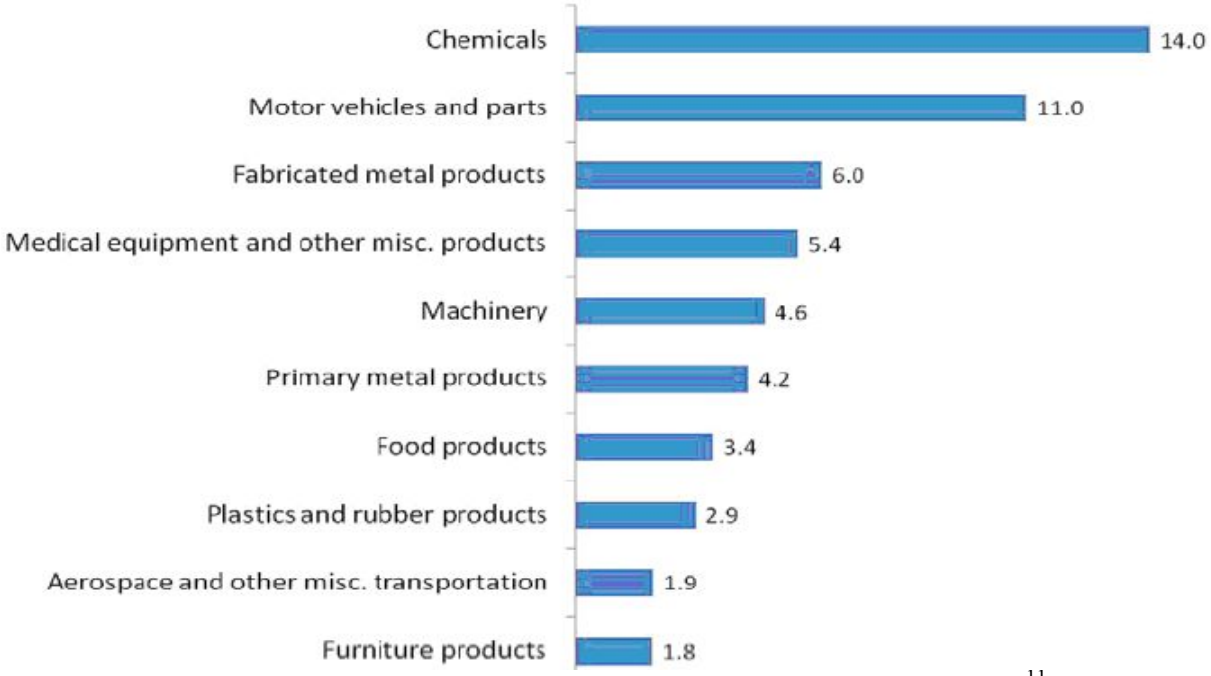

Figure 6. Top 10 Indiana Manufacturing Sectors, 2007 (GSP, billions)[11].

According to the Bureau of Economic Analysis, the Bureau of Labor Statistics, and based on CEO Survey[12], Indiana was ranked as a fifth best state in the U.S. for business in 2012. Tables 2 and 3 present Indiana's manufacturing rating among the states in the U.S.

Table 2. *Indiana's Ranking Among the Peer States and nationally*[10]

Leading business and economic indices	Peer state rank	National rank
State Business Tax Climate Index (Tax Foundation)	4	12
Best & Worst States [to do business] Survey (Chief Executive Magazine)	3	11
Competitiveness Index (Beacon Hill Institute)	8	44
Economic Competitiveness Index (American Legislative Exchange Council)	8	47
2007 State and Local Tax Burden (Public Policy Institute of New York)	4	23
Economic Freedom Index (Pacific Research Institute)	3	14
Small Business Survival Index (Small Business & Entrepreneurship Council)	4	20
2007 Cost-of-Doing-Business Index (Milken Institute)	2	14
State New Economy Index (Kauffman Foundation)	8	36
State Technology & Science Index (Milken Institute)	8	33

Note: Indices cited were published in 2008, unless otherwise stated. Some index rankings results were reversed from published rank in order to make them consistent across the different indices as presented here. The rankings are among the eight peer states, 1 = best and 8 = worst.

Table 3. *Manufacturing Indicator for U.S. and Indiana's Ranking Among the Peer States*[10]

Manufacturing Indicators	US	IN	% Change 2000 to 2007 US	% Change 2000 to 2007 IN	Rank (1-8)
Manufacturing share of real GDP/GSP	13.6%	28.2%	-6.1%	-5.4%	6
High-tech manufacturing share of real GDP/GSP	4.8%	7.3%	39.3%	29.7%	4
Manufacturing employment (thousands)	13,882.6	549.97	-19.6%	-17.2%	7
High-tech manufacturing employment (thousands)	2,468.7	68.1	-19.4%	-5.4%	1
Share of U.S. high-tech manufacturing employment	2.00% (U.S. avg.)	2.76%	2.0%	17.4%	1
Manufacturing wage per employee (US$)	$53,804	$51,340	25.3%	25.2%	5
Manufacturers' capital expenditures (US$ billions)	$135.8	$5.3	-12.3%	-13.3%	4
Industrial R&D expenditures (US$ billions, 2005)	$226.2	$4.6	13.3%	72.8%	3
Real manufacturing output (US$ billions)	$1,571.7	$58.5	10.2%	1.1%	8
Real manufacturing output per worker (US$ thousands)	$113.6	$106.5	37.9%	22.0%	7
Value added per production worker (US$)	$249,139	$224,781	48.8%	39.8%	5
Exports of manufactured goods (US$ billions)	$1,022.1	$25.3	44.4%	68.6%	4

Note: Data are 2007 figures, unless stated otherwise. The rankings are among the eight peer states, 1 = best and 8 = worst, based on the growth rate from 2000 to 2007.
Sources: Bureau of Economic Analysis, Bureau of Labor Statistics, The National Science Foundation, U.S. Census Bureau, Milken Institute.

According to Manufacturing & Logistic Report Card that was released in June 2012 by Conexus Indiana and the Ball State Center for Business and Economic Research[13]. Indiana ranks the state ranks 10th in manufacturing exports per capita and first in income derived from foreign manufacturing investment.

Indiana has approximately 550,000 manufacturing employees, or 4 % of the nation's total in 2007. Although manufacturing contributes up to 30 % to Indiana's economy, the series of economic recession negatively impacted on production and jobs. Milken Institute reports that since 2000 Indiana shed 114,500 jobs. Most of the job losses were in the transportation equipment and primary metal manufacturing industries. Though employment declined, the rates of decline in both high-tech and non-high-tech manufacturing were not as severe as the national average. Only high-tech manufacturing jobs rebounded after employment in the state's entire manufacturing sector bottomed out in 2003[10]. In 2011 study by the Manufacturing Institute and Deloitte Consulting (http://www.themanufacturinginstitute.org/) found that manufacturing companies recognized a high-skilled and flexible workforce as the most significant factor which drives their company's business success. The National Skills Coalition 2010 report found that roughly half of Indiana's jobs require middle skill credentials, yet there is a deficit in middle skill workers which will last for another 15 years if nothing is done to turn the tide.

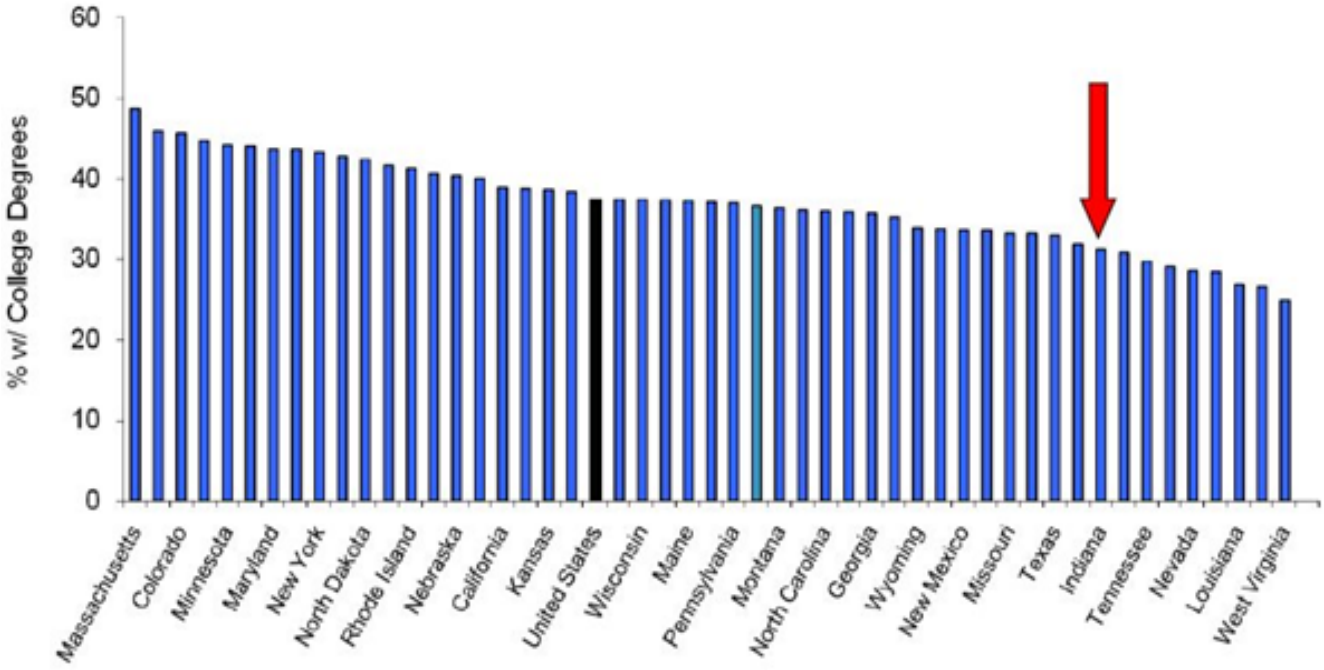

Figure 7. Adult Ages 25-64 with at least an Associate's Degree.

Modern Challenges for Advanced Manufacturing

Nationwide modern challenges for advanced and high-tech manufacturing can be outlined as the following:

- High Federal and state taxes;
- Sometimes unwelcomed business climate to high-tech companies;
- New technologies are slowly adapted by Small and Medium Size (SMS) enterprises, which often play a vital role in supply chain. There are many gaps between Research and Development (R&D) activities and the deployment/ implementation of technological innovations in domestic sectors;

- Strong public stereotypes (transformed from generations to generations) that manufacturing is unsecure and a 'bad' job. Repetitive reporting has created an image that manufacturing jobs do not offer job security. The conventional wisdom about manufacturing evokes images of the past and leads one to believe that jobs in this sector are dirty, noisy, repetitive, and dangerous and that manufacturing operations are harmful to the environment [15].
- Lacks in qualified workers because of their insufficient education and gaps in STEM disciplines. Industry participants have consistently raised concerns about the "largest gap" in American educational system- it does not produce people with the technical knowledge, basic business skills, people skills, and problem solving abilities necessary to succeed in a modern manufacturing facility[15].
- A consequence of all the above leads to the loss of the U.S. leadership in AM and transfer of AM businesses to overseas, specifically to Asia region. The quality of the U.S. workforce is not the primary reason manufacturing companies to locate facilities outside the United States; however, work force quality is a concern to industry and a top consideration when making a decision about where a new facility will be located[15].

Recommendations for Improvement

Advanced manufacturing is a matter of fundamental importance to the economic strength and national security of the United States. To address current challenges, NSTC in the *National Strategic Plan for Advanced Manufacturing* [16] outlined five strategic objectives. If those objectives are fulfilled, they will have a significant, immediate, and long-lasting positive impact on U.S. advanced manufacturing. This strategy seeks to achieve the following:

- *Accelerate investment in advanced manufacturing technology, especially by small and medium-sized manufacturing enterprises, by fostering more effective use of Federal capabilities and facilities, including early procurement by Federal agencies of cutting-edge products.*
- *Expand the number of workers who have the skills needed by a growing advanced manufacturing sector and make the education and training system more responsive to the demand for skills.*
- *Create and support national and regional public-private, government-industry-academic partnerships to accelerate investment in and deployment of advanced manufacturing technologies.*
- *Optimize the Federal government's advanced manufacturing investment by taking a portfolio perspective across agencies and adjusting accordingly.*
- *Increase total U.S. public and private investments in advanced manufacturing research and development (R&D).*

Highly-skilled and creative professionals are essential to a corporation's long-term competitiveness. Even with current unemployment near 9%, advanced manufacturing positions are available in a wide range of industries. Jobs for unskilled labor are declining, but jobs for skilled technicians are increasing at a rate that surpasses the availability of qualified candidates.

Unfortunately, the image of manufacturing and the public perception that it can provide long-term and desirable careers have been discolored. In a recent survey conducted by the Manufacturing Institute, 67% of respondents reported a moderate-to-severe shortage of available, qualified

workers, and 56% anticipated the shortage to grow worse in the next 3 to 5 years. The image of manufacturing needs a complete restoration, removing false impressions based upon partial truths and realities of the past. In the recent report to the President[15], Education and Workforce Development Workstream (AMP E &WDW) states that the most impactful recommendations for improvement should be addressed to the high school and community college levels, followed by undergraduate education. To secure and develop the talent workforce pipeline, the following must be accomplished through public/private partnerships:

1. *Create an aggressive, integrated "Image of Manufacturing" public service announcement campaign that would raise awareness and correct misperceptions of manufacturing in the United States.*

The AM industries in the U.S. should launch a nationwide campaign (including media) to restore the image of manufacturing careers, with outreach support from existing associations such as the Society of Manufacturing Engineers (SME), the National Association of Manufacturers (NAM), and the Institute of Industrial Engineering (IIE).

2. *Provide support for veterans who possess the skills to fill technical manufacturing jobs, starting with the addition of a training module on advanced manufacturing.*

According to the U.S. Bureau of Labor Statistics, the unemployment rate for veterans who served on active duty in the U.S. Armed Forces at any time since 2001 (a group referred to as Gulf War-era II veterans) was 12.1 % in 2011 [17]. Veterans possess many of the missing and key important skills that are vital to advanced manufacturing. Therefore, veterans must be aware of career opportunities in manufacturing, and industries must be aware that veterans can provide solutions to many existing employment problems.

3. *Build a certification and accreditation program to create national standards for advanced manufacturing.*

Certifications and accreditations for skills in advanced manufacturing are needed. These educational certificates should be portable from institution to institution (enabling mobility between regions) and from colleges to jobs and back.

4. *Enhance the role of research universities in defining the discipline of advanced manufacturing.*

The major research universities have a special responsibility to establish through degree programs what advanced manufacturing means and why it is so vitally important. These degree programs should be comprehensive in their integration of technologies (e.g., robotics and advanced automation) with methods (e.g., supply-chain management). Once established, the major universities must collaborate to establish a new educational model and uniform standards that can propagate nationally to an aligned set of education and training programs at the secondary, certificate, sub-baccalaureate, and baccalaureate levels. Research universities also must play a key role in producing the next generation of educators and industrial leaders. In so doing, these institutions will not only add to the profession, but will also greatly improve the image of manufacturing as a challenging and rewarding career. The creation of graduate degree programs in advanced manufacturing (e.g., through the NSF Integrative Graduate Education and Research

Traineeship program and national MS and PhD Fellowships in advanced manufacturing) should be encouraged.

Specific attention should be paid to the Research & Development activities. A gap exists between R&D and the deployment of technological innovations in domestic production of goods. This gap has contributed to the erosion of key indicators, such as the balance of trade in advanced technology products [1].

5. *Invest in community colleges and project-based curricula to build advanced manufacturing skills.*

Historically, community colleges have the greatest impact on the workforce development. Although community colleges provide some of the missing education, a significant gap remains. Most of the gap can be found at the secondary level, where many students are not prepared to join the manufacturing workforce. Workers lack general workplace skills such as problem solving, social interaction, and teamwork. Basic communication skills of reading, writing, and mathematics are also inadequate. As a result, businesses often must train employees in areas of STEM before they can make needed contributions [15]. Specific emphasis in the President report was given on the importance of project-based learning in community colleges. The best practices of successful partnership between industries and community colleges should be captured and propagated. Local government can encourage these partnerships by funding progressive benchmark initiatives and defunding legacy status quo programs[15].

Obama's Initiatives

The recent initiatives of the U.S. President regarding improving a national business climate and economic situation for advanced manufacturing can be summarized as the following:

1. In June 2011, the President established the Advanced Manufacturing Partnership (AMP), which is led by a Steering Committee that operates within the framework of the President's Council of Advisors on Science and Technology.

2. On February 2012, the President proposed a national commitment to train two million workers with skills that will lead directly to a job. This is an $8 billion *Community College to Career Fund*. This initiative was co-administered by the Department of Labor and the Department of Education (http://www.whitehouse.gov/the-press-office/2012/02/13/fact-sheet-blueprint-train-two-million-workers-high-demand-industries-th).

3. On March 2012, President Obama announced a new $1 billion proposal for a *National Network for Manufacturing Innovation* (*NNMI*) to create fifteen Institutes for Manufacturing Innovation around the Country. These institutes function as regional centers of manufacturing excellence that will assist U.S. manufacturers to become more competitive and encourage investment in the United States. Each institute should be the part of the national network. NNMI should be a partnership among the Departments of Defense, Energy, and Commerce, and possibly other civilian agencies.

4. On September 2012, the Obama administration announced a $40 million multi-agency competition called *the Make it in America Challenge.* This announcement builds on the efforts to encourage any domestic and global companies to increase investment in the United States. The president's plan includes eliminating tax incentives for companies that ship jobs overseas and providing tax credits for companies that bring jobs back, investing in American workers to ensure they have the skills they need. This competition was funded by the U.S. Department of Commerce's Economic Development Administration, National Institute of Standards and Technology Manufacturing Extension Partnership, and the U.S. Department of Labor's Employment and Training Administration.

5. The United States Department of Commerce reported that on October 9th 2012 Obama Administration announced $20 million for 10 Public-Private Partnerships to support American manufacturing and inspire investment in the U.S. (http://www.commerce.gov/news/press-releases/2012/10/09/obama-administration-announces-20-million-10-public-private-partnersh). According to that, ten partnerships were selected through the *Advanced Manufacturing Jobs and Innovation Accelerator Challenge*, which was a competitive multi-agency grant process to support initiatives that strengthen advanced manufacturing at the local level. These public-private partnerships consist of businesses, colleges, nonprofits and other local stakeholders that 'cluster' in a particular area. The funds help the winning clusters support local efforts to accelerate job creation through a variety of projects, including initiatives that connect innovative small suppliers with large companies.

6. Starting from 2013, the President's Budget proposed $2.2 billion in advanced manufacturing R&D, which was a 19% increase over the 2012 fiscal year.

7. The President called for ambitious business tax reform (http://www.treasury.gov/resource-center/tax-policy/Documents/The-Presidents-Framework-for-Business-Tax-Reform-02-22-2012.pdf) that encourages companies to bring jobs and investment to the U.S. The President proposed to lower rates for manufacturers to a maximum of 25%; require companies to pay a minimum tax on overseas profits; expand, simplify and make permanent the R&D Credit; increase the tax deduction for advanced manufacturing; support investment in next generation energy manufacturing; eliminate deductions for companies that ship jobs overseas; and provide tax credits for companies that bring jobs home.

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