CMAP

Metropolitan Chicago's Manufacturing Cluster: **A Drill-Down Report on Innovation, Workforce, and Infrastructure**

Technical Report, February 2013

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Introduction

Metropolitan Chicago -- one of the world's great economic centers -- benefits from a broad mix of industries yet also realizes significant gains through its economic specializations. These "industry clusters" spur innovation, foster collaboration, and help position the region to better compete on the global stage.

Metropolitan Chicago's GO TO 2040 comprehensive plan calls for strategically organizing the region around its existing and emerging clusters of specialization. Of all the region's industry specializations, its manufacturing cluster stands out historically as a key driver of economic growth, helping transform the region into the global economic powerhouse it is today. Though other clusters have always been important, "the region's economy was built on manufacturing."[1]

Recently this cornerstone of the economy has come under heightened pressure from manufacturing regions across the globe. While metropolitan Chicago's manufacturing cluster continues to realize productivity gains, employment has fallen, especially during the last ten years. This drill-down report analyzes the challenges and opportunities in the region's manufacturing cluster that affect competitive advantage in the 21st Century. The scope of the report is the seven northeastern Illinois counties of the Chicago Metropolitan Agency for Planning's (CMAP) planning area. Unless otherwise noted, data supporting the analysis are for those seven counties.

Metropolitan Chicago's Manufacturing Cluster

- Employs **580,000 workers**, second largest such cluster in the nation.
- Provides wages **27 percent higher** than the regional average.
- Fuels innovation — **85 percent** of all private R&D in the region.
- Generates over **$65 billion annually**, second largest segment of the regional economy.
- Creates **largest ripple effect** of any industry (one manufacturing job supports at least two more in the region).
- Produces **two-thirds** of the region's exports.
- Leverages region's locational advantage as **freight hub** of the nation.
- Influences nearly **every major industry** in the region.

Metropolitan Chicago's Manufacturing Cluster, the first chapter of this report, provides a statistical overview of the industries comprising the cluster. It also introduces a definition of advanced manufacturing by looking at Product, Process, and People indicators and a scorecard that combines the three indicators as a way to measure advanced manufacturing industries.

[1] Bill Testa and Norman Wang, "Manufacturing as Midwest Destiny," *Federal Reserve Bank of Chicago*, February 3, 2012.

The chapter **International and National Developments** describes how metropolitan Chicago became a manufacturing powerhouse and then situates contemporary manufacturing within an era of globalization and intense competition.

The bulk of the cluster drill-down focuses on three areas with the most potential to affect future economic vitality: **Innovation, Infrastructure,** and **Workforce**. Each theme in the chapter highlights challenges and opportunities internal to the region and concludes with a set of regional strategies to better align resources and investments with what manufacturing needs to stay competitive in the 21st Century.

Chapter 1: Metropolitan Chicago's Manufacturing Cluster

Metropolitan Chicago's manufacturing cluster is one of the key drivers of the regional economy. In 2011, the cluster employed over 580,000 individuals regionally, making it the second largest manufacturing cluster in the country behind only Los Angeles. Not only does the cluster serve as a major regional employer, it also provides on average better paying jobs -- with about 13 percent of regional employment, the manufacturing cluster contributes over to 18 percent of all employee earnings. From developing new products and technologies to exporting consumer goods around the world, the massive output of the cluster supports a substantial portion of the regional workforce while bringing new dollars into the economy.

The Cluster Approach to Regional Economic Development

An industry cluster is a group of interdependent firms and related institutions that draw a productive advantage from their geographic concentration and regional support networks. GO TO 2040 -- metropolitan Chicago's comprehensive plan -- recommends a cluster-based approach to economic development because of its enhanced ability to describe a regional economy, recognize the relationships between firms, and identify strategies building on embedded strengths. The plan also shows how clusters of regional specialization can position the economy for growth: individual firms within a cluster share common resources and technologies, rely on a similar labor pool and institutions, and share knowledge and strong relationships that confer a competitive advantage compared to isolated firms.[2] Following the recommendation of GO TO 2040, CMAP has undertaken a cluster series on the regional economy. In July 2012, CMAP released the first of the cluster reports, focusing on freight. This second drill-down report uses the same cluster approach to analyze regional manufacturing.

CMAP's Cluster Framework and Composition

A cluster is different than a traditional industry sector in that it comprises multiple types of businesses that are connected not only through similar economic activities but also networks and transactions. So while the manufacturing *sector* covers only firms directly engaged in transforming materials into new products, the manufacturing *cluster* encompasses these core firms but also those responsible for developing new products and processes for manufacturing, providing inputs and supply chain support, and helping manufacturers get their goods to market.

[2] CMAP, GO TO 2040 comprehensive regional plan, 2010.

This cluster drill-down report organizes industries within the manufacturing cluster into four categories based on their primary activities:

- **Core industries** drive economic activity in the cluster and include industries using mechanical, physical, or chemical processes to transform materials and components into new products.
- **Direct supply and input industries** provide the core industries with inputs necessary for production. These include raw materials, logistics and supply chain management, and power generation and distribution.
- **Indirect support industries** provide research, design, and development services germane to the core industries.
- **Customer industries** purchase goods or services from the core industries. In this analysis, customer industries are represented by truck, rail, air, and water freight carriers.

Figure 1. Metropolitan Chicago's Manufacturing Cluster

Source: CMAP analysis, 2012.

Overview of the Manufacturing Cluster

Of the approximately 580,000 workers in Chicago's regional manufacturing cluster, close to two-thirds are employed in core manufacturing industries, another 18 percent in support industries, and 12 percent in customer industries. Supply industries, with about four percent of cluster employment, are the smallest component of the cluster.

The four different segments of the cluster have experienced differing growth trends this past decade. Regional employment in core manufacturing industries fell by almost a third between 2001 and 2011; this drop mirrors larger trends in domestic manufacturing. Employment in support industries also fell, chiefly due to a loss of research and development (R&D) unique to the Chicago region. In contrast, employment in the supply component of the cluster grew by 16 percent, and the customer segment increased by a single percentage point.

Location quotients (LQs) compare the distribution of employment in a regional industry to the national average to measure where the region maintains a specialization. An LQ of one means the industry has the same distribution of employment regionally as it does nationally; an LQ below one signifies a below-average proportion of employment for a regional industry, while an LQ above one indicates an above-average proportion. For an economy as large and broad as metropolitan Chicago, an LQ at or near 1.1 suggests regional specialization. The cluster's LQ for core manufacturing industries is 1.09, meaning that the cluster employs nine percent more personnel than would be expected from the national average. The cluster has even more pronounced specializations in the supply (LQ of 1.24) and customer (LQ of 1.19) segments of the manufacturing cluster. Of the four, only the support segment of the cluster was under-specialized in the region.

Table 1. Manufacturing Cluster At-a-Glance

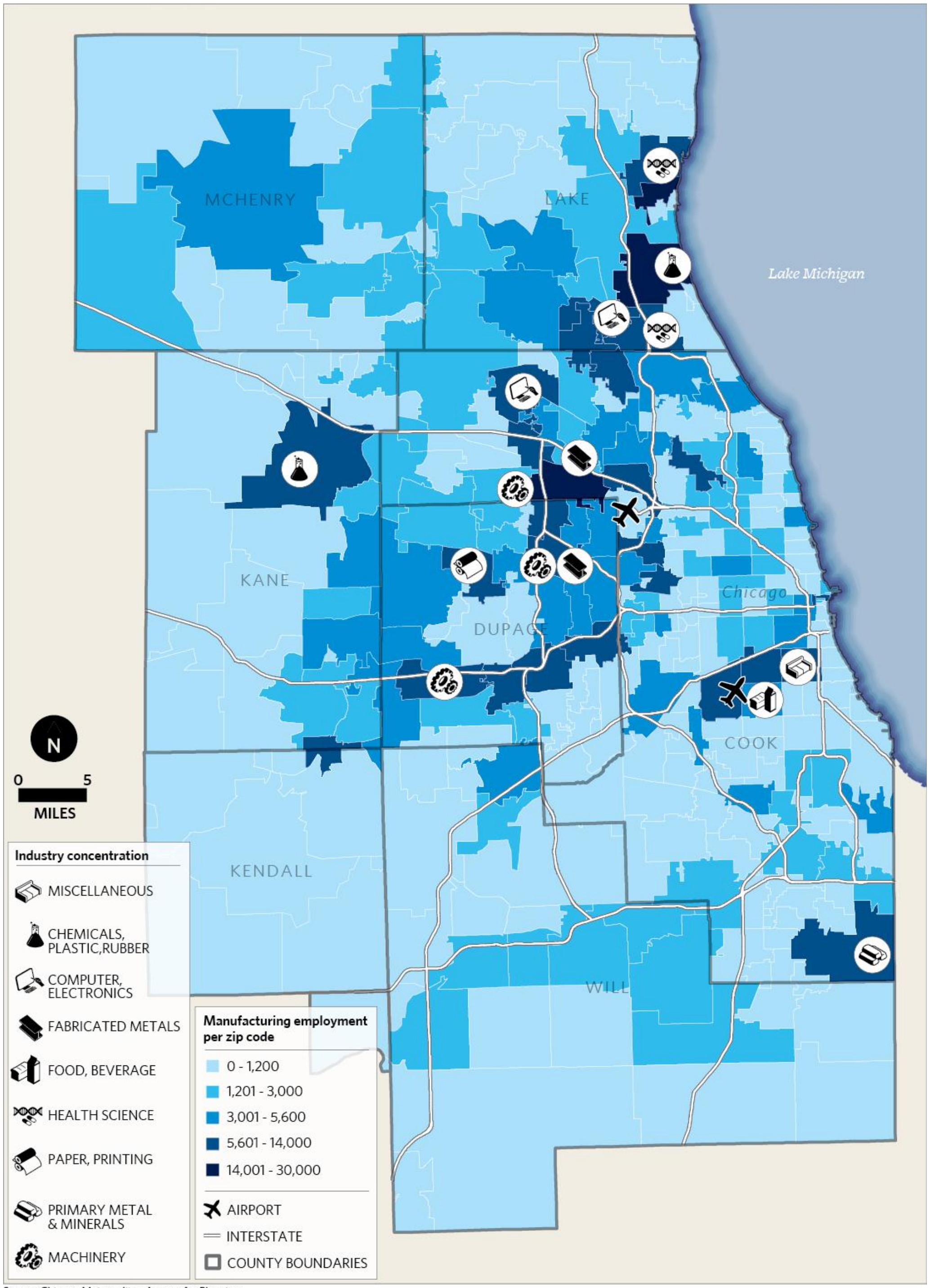
	Core	Supply	Support	Customer
Employment (2011)	374,243	24,097	108,594	73,279
Employment Change (2001-11)	-30%	16%	-7%	1%
Concentration Measure (LQ)	1.09	1.24	0.94	1.19

Source: CMAP Analysis of Economic Modeling Specialists Inc. data.

Geography of the Manufacturing Cluster

Metropolitan Chicago's manufacturing cluster is truly regional in nature, stretching from historic manufacturing districts in Chicago out to all the counties of the region. The area around O'Hare is a major manufacturing node for the cluster. Further employment centers include health science manufacturing in Lake County, an electronics concentration in northern Cook, machinery and fabricated metals in DuPage, and primary metals in southeastern Cook. The following map shows total employment in core manufacturing by zip code. The added symbols depict a few areas that are particularly concentrated in certain industries.

Figure 2. Regional Manufacturing Employment



Source: Chicago Metropolitan Agency for Planning.

The remainder of this chapter drills down into the core, supply, support, and customer segments of the manufacturing cluster, starting first with core manufacturing industries and introducing the concept of advanced manufacturing.

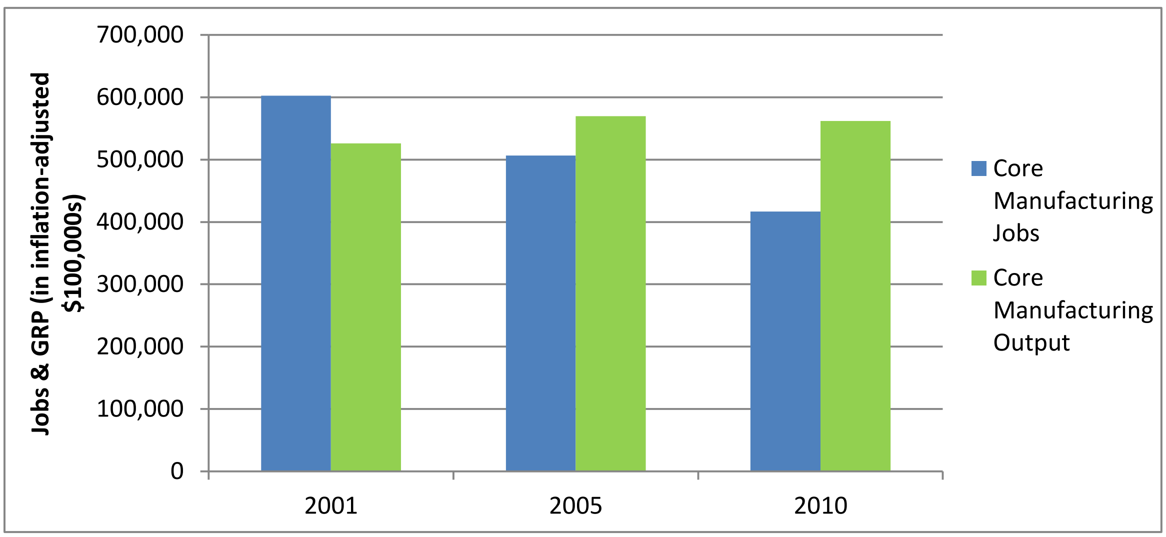
Core Manufacturing in the Chicago Region

Of the approximately 580,000 workers in Chicago's regional manufacturing cluster, core manufacturing firms employed 375,000 individuals in 2011. This employment center of core manufacturing workers is the second largest in the nation though employment industries fell by over 160,000 the past decade. Regional employment loss mirrors larger trends in American manufacturing as globalization allowed domestic firms to offshore production to developing countries and technology continued to replace workers. By offering not only cheaper labor, but also supply chain capabilities and investments in infrastructure, China in particular was the destination for many offshored production jobs. As a result, in both Chicago and the nation, core manufacturing employment contracted by a third.

Manufacturing is the second largest component of the region's broad economy, contributing over $64 billion annually to gross regional product.

Even with employment decline, manufacturing productivity in the region continues to increase. After a slowdown during the recession, manufacturing output as measured by gross regional product rose to $64 billion in the tri-state area in 2010. This impressive output makes manufacturing the second largest component of the region's broad economy. [3]

Figure 3. Regional Manufacturing Productivity and Employment Change, 2001-10



Source: CMAP analysis of Bureau of Economic Analysis and EMSI data using 2005 chained dollars.

After a decade low in 2009 from the recession, manufacturing productivity rebounded in 2010, contributing $64.5 billion (or $57 billion in inflation-adjusted dollars) to the regional economy. These productivity gains come even as the regional workforce has contracted, showing how firms have found ways to do more with less. Some employment loss may be from firms' increased use of temporary help workers to fill production positions. The chart measures core manufacturing jobs and output for the 14 county tri-state economy as customized data for the CMAP seven-county region were lacking.

[3] CMAP analysis of U.S. Bureau of Economic Analysis gross regional product data.

Diversified Output

Compared to other manufacturing centers in the U.S., metropolitan Chicago stands out because of its broad output across almost every core industry sector. Most metropolitan areas specialize in just a few manufacturing industries. In Seattle for example, almost half of all manufacturing jobs are in the aerospace industry while in Silicon Valley close to 70 percent of manufacturing employees work in the computers/electronics industry.[4] The Midwest's historic manufacturing specialization has been in motor vehicles and parts, with Detroit being the best known example.

Instead of an anchor industry like autos in Detroit or planes in Seattle, manufacturing output in the Chicago region is distributed among many different industries. No single industry in the region accounts for more than 19 percent of manufacturing employment. This diversified manufacturing core has both limitations and advantages. For the former, manufacturing industries have quite different skill and supply chain needs -- a chemical manufacturing worker's skills are likely incompatible with the computer manufacturing industry. Regions that specialize in just a few manufacturing industries can devote the bulk of their resources towards specialized workforce, R&D, and supply chain initiatives.

On the flip side, overreliance on a single industry in today's global economy can be a precarious endeavor. Detroit's struggles in the face of external competition starting with Japanese automakers exemplify the drawbacks of overspecialization. While metropolitan Chicago lost some of its initial manufacturing specializations, the region's broad manufacturing base can better weather the ups and downs of individual industries.

This analysis divides the region's core manufacturing industries into nine categories (and corresponding North American Industry Classification System [NAICS][5] codes) based not only on similar products but also similar skills sets, labor intensity, and processes.

- Machinery, including transportation, electrical, and commercial/industrial machinery (333, 335, 336)
- Fabricated Metals (332)
- Food and Beverage (311-312)
- Chemicals, Rubber, Plastics (325 except 3254, 326)
- Primary Metals, Minerals, and Petroleum (324, 327, 331)
- Paper and Printing (322, 323)
- Furniture, Apparel, and Other Manufacturing (313-316, 321, 337, 3399)
- Computers and Electronics (334)

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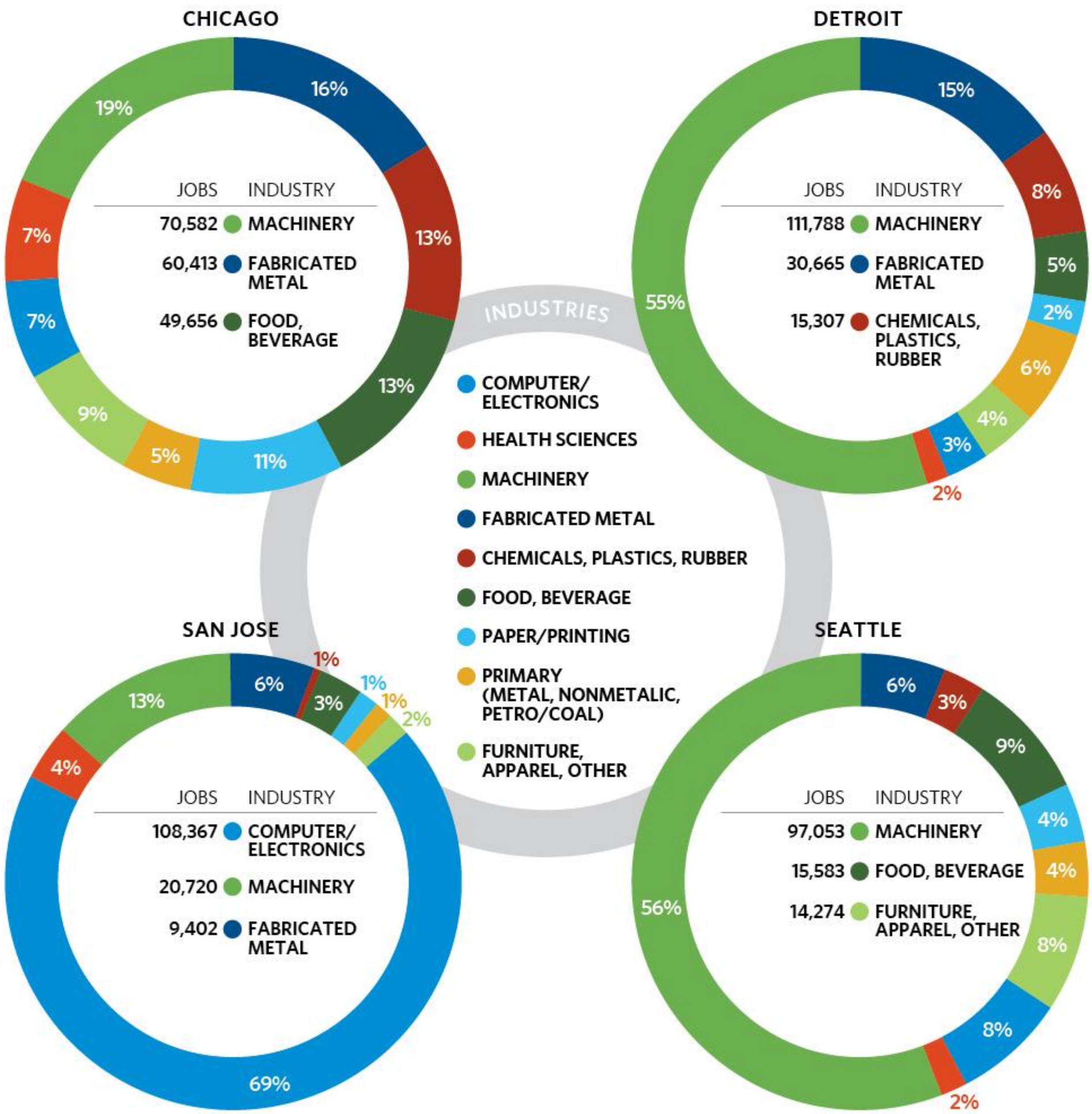
[4] Helper et al., April 2012.

[5] The North American Industry Classification System is the standard used by Federal statistical agencies in classifying business establishments and measuring employment.

- Health Sciences Manufacturing, including pharmaceuticals and medical equipment (3254, 3391)

Figure 4. Metropolitan Chicago's Diversified Manufacturing Compared to Three Specialized Regions

Manufacturing concentrations by region

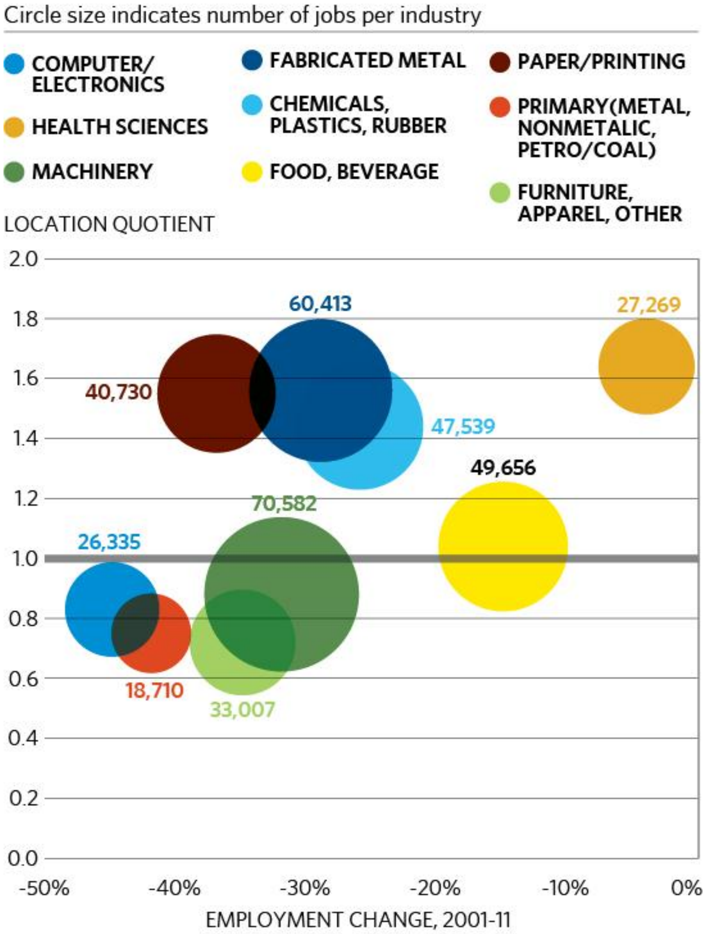


Source: CMAP analysis of BLS data, 2012.

The following chart depicts the size and concentration of each of the region's nine core sectors, as well as how employment in each sector has been impacted this past decade by heigthened global competition.

How to Read the Bubble Charts
This report uses a series of bubble charts to visualize data about the manufacturing cluster across three metrics: current employment, employment change, and LQ. The horizontal axes in each chart measures regional employment change by industry for the last ten years while the vertical axes shows the industry's 2011 LQ. The circle size of each industry indicates current regional employment

Figure 5. Diversified Manufacturing within the Chicago Region



Source: CMAP analysis of EMSI data, 2012.

Employment loss across core sectors this past decade illustrates the challenges regional manufacturing faces in a globalized economy. The region's maintained productivity growth however evidences how cluster firms have made rapid improvements in skills, methods, and output. GO TO 2040 terms this shift towards high-tech products and processes "advanced manufacturing."[6] The next section provides a data-based definition of advanced manufacturing and then shows how the region's continued shift to advanced manufacturing will be critical for future cluster growth.

Advanced Manufacturing

The last decade of global manufacturing illustrates how metropolitan Chicago's competitive advantage lies not in low skilled, labor intensive activities vulnerable to offshoring, but in manufacturing that leverages advanced skills, methods, and output. To capitalize on this advanced manufacturing the region needs to draw on the same competitive advantages that fueled manufacturing growth in the past -- process improvements, product innovation, and a deep pool of skilled workers -- to thrive in a new era of global manufacturing. Following the framework of GO TO 2040, this analysis looks at metropolitan Chicago's core manufacturing industries using an advanced lens. For reasons to be explored in this report, advanced manufacturing across not only core industries but support, supply, and customer segments of the cluster has the best potential to reverse job loss and continue productivity gains.

Defining "Advanced Manufacturing": Product, Process, and People

While the future of U.S. manufacturing will look much different than the past, there is less agreement on how to define this trend toward advanced manufacturing. Through an extensive review of national, state, and regional studies on advanced manufacturing as well as interviews with key stakeholders and business leaders, CMAP has developed a "3P approach" -- **Product**, **Process**, and **People** -- to define the following characteristics of advanced manufacturing:

> **Product**
> Advanced manufacturing products are complex, innovative, and difficult to replicate.
>
> **Process**
> Advanced manufacturing processes (regardless of end product) are continually improved to achieve new efficiencies and cost savings.
>
> **People**
> Advanced manufacturing workers have specialized skills that maximize the commercial impact of these products and processes.

While it is possible for a firm to be advanced by performing well on a single of the three indicators, the most advanced firms are those that demonstrate all three characteristics of advanced manufacturing.

[6] CMAP, "GO TO 2040," 2010, p. 190.

Advanced Manufacturing Scorecard

Using the "3P" approach of Product, Process, and People, CMAP has developed a scorecard that measures advanced manufacturing by aggregating individual firms into industry groupings.[7] While firms within industries vary (some individual firms within lower scoring industries will in fact be advanced), CMAP's advanced manufacturing scorecard shows that certain industries tend to have a higher degree of advanced firms. The following section describes how individual manufacturing industries ranging from fabricated metals to food to chemicals fare on each of these 3P measures of advanced manufacturing.

Advanced Manufacturing Scorecard: Product

For the Product portion of the scorecard, CMAP developed an advanced manufacturing innovation index that shows certain industries have been more likely than others to produce new manufactured products. The index uses five metrics -- patent output, R&D intensity, new product development, percent of architecture and engineering occupations, and productivity growth -- to gauge an industry's innovation standing. The index is based off the work of Helper et al.[8] adapted to the Chicago region. The following table reports the results of the index, with the lower the score the better the performance of the industry across all metrics.

Table 2. Advanced Manufacturing Scorecard: Product

Industry	Score (Lower = More Advanced)
Computers and Electronics	23
Health Sciences	31
Machinery	48
Chemicals, Rubber, Plastic	55
Manufacturing average	59
Fabricated metals	75
Furniture, Apparel, and Other Manufacturing	90
Primary Metals and Minerals	92
Food and Beverage	102

Note: Sufficient data not available for Paper and Printing, Petroleum and Coal Products, and Medical Supplies and Miscellaneous Manufacturing.

Source: CMAP analysis of Brookings data.

Advanced Manufacturing Scorecard: Process

The second component of the scorecard evaluates if an industry is advanced based on the processes employed by measuring value added as a percentage of the total shipment value. Value added represents the difference between the value of the final output and the total cost of

[7] The scorecard aggregates to the industry level because it is not possible to survey the approximately 30,000 individual firms in the regional manufacturing cluster.

[8] Susan Helper, Timothy Krueger, and Howard Wial's "Why Does Manufacturing Matter? Which Manufacturing Matters?" *Metropolitan Planning Program at Brookings*, February 2012.

all intermediate inputs. In simpler terms, it measures how much of the value of the manufactured good is due to the manufacturing process in-house instead of just the initial value of raw materials and inputs. Value added is not a perfect Process indicator (see following section on data limitations of the scorecard), yet the U.S. Census Bureau considers value added the best available measure for comparing the economic importance of manufacturing industries, and high value added has been used elsewhere to indicate advanced manufacturing.[9]

The following table relates value added as a percentage of total shipment value in each industry, using U.S. Census data at the national level. The higher the percentage, the better the industry performs on this measure of advanced manufacturing.

Table 3. Advanced Manufacturing Scorecard: Process

Manufacturing Industry Rank on Value Added Indicator	
Industry	Value Added as Percentage of Total Value of Output (Higher = More Advanced)
Health Sciences	71%
Computers and Electronics	64%
Fabricated Metals	53%
Paper and Printing	50%
Furniture, Apparel, and Other Manufacturing	48%
Machinery	46%
Manufacturing Average	45%
Food and Beverage	44%
Chemicals, Plastics, Rubber	44%
Primary (metals, mineral, petroleum and coal)	24%
Source: CMAP analysis of U.S. Census Annual Survey of Manufacturers data.	

Advanced Manufacturing Scorecard: People

The third section of CMAP's advanced manufacturing scorecard uses wages as a proxy to measure advanced skills. Other studies have shown how manufacturing workers with high-tech skills are paid substantially more, arguing that the high-income economy is a good indicator of advanced manufacturing.[10] Intuitively this makes sense: private firms are in business to make a profit, so a "company only employs these high cost workers in large numbers when advanced products or processes demand it."[11] Advanced manufacturing must employ workers with skills to implement increasingly complex processes, advance new

[9] Daniel Luria and Joel Rogers, "Manufacturing, Regional Prosperity, and Public Policy," in Retooling for Growth, eds. Richard M. McGahey and Jennifer S. Vey, Brookings Institution Press p.258; Michael Ettlinger and Kate Gordon, "The Importance and Promise of American Manufacturing," Center for American Progress, April 2011.

[10] Tassey, 2009, p.6.

[11] Missouri Department of Economic Development, "Missouri Targets Advanced Manufacturing," July 2011, p.3.

products, as well as respond to unexpected circumstances. The following table uses regional data to depict the 2012 average annual wages for manufacturing workers in metropolitan Chicago. The higher the average annual wage, the better the industry performs on the People measure of advanced manufacturing.

Table 4. Advanced Manufacturing Scorecard: People

Manufacturing Industry Rank on Regional Wages	
Industry	2012 Average Annual Wage (Higher = More Advanced)
Health Sciences	$106,700
Computers and Electronics	$74,697
Primary (metals, minerals, petroleum and coal)	$64,429
Machinery	$64,020
Manufacturing Average	$61,907
Chemicals, Plastics, Rubber	$60,003
Fabricated Metals	$54,552
Paper and Printing	$53,700
Food and Beverage	$53,700
Furniture, Apparel, and Other Manufacturing	$46,707

Source: CMAP analysis of Economic Modeling Specialists Inc. data.

Data Limitations of the Advanced Manufacturing Scorecard

The advanced manufacturing scorecard combines the three Product, Process, and People indicators into a single visual, giving researchers a tool to measure manufacturing based on extensive supporting evidence. Limitations in available data mean the scorecard is not a perfect measure, instead best viewed within the other findings of the report. In particular, the Process indicator may not capture some improvements by manufacturers that operate more as distributors and less as production firms. As process improvements are highly firm-specific, fewer data sources can capture this change. Of all available sources only value added captures this process change, yet this was limited to national data, so the indicator makes an assumption that regional industries do not differ greatly from national proportions. Finally, variations between firms mean that even the industries scoring the lowest on the scorecard will still have their share of advanced firms, and future innovations can always change the trajectory of manufacturing industries. With these data limitations in mind, the advanced manufacturing scorecard uses the best available data to show how industries in aggregate differ on Product, Process, and People indicators.

Advanced Manufacturing Scorecard Summary

The following summary graphic shows the results of the advanced manufacturing scorecard by the Product, Process, and People measures and then an overall rank combining the three.

RANK	PRODUCT	PROCESS	PEOPLE	OVERALL RANK
1	COMPUTER/ ELECTRONICS	PHARMA/ MEDICAL SUPPLY	PHARMA/ MEDICAL SUPPLY	PHARMA/ MEDICAL SUPPLY
2	PHARMA/ MEDICAL SUPPLY	COMPUTER/ ELECTRONICS	COMPUTER/ ELECTRONICS	COMPUTER/ ELECTRONICS
3	MACHINERY	FABRICATED METAL	PRIMARY (METAL, NONMETALIC, PETRO/COAL)	MACHINERY
4	CHEMICALS, PLASTICS, RUBBER	PAPER, PRINTING	MACHINERY	CHEMICALS, PLASTICS, RUBBER
5	PAPER, PRINTING	FURNITURE, APPAREL, OTHER	CHEMICALS, PLASTICS, RUBBER	FABRICATED METAL
6	FABRICATED METAL	MACHINERY	FABRICATED METAL	PAPER, PRINTING
7	FURNITURE, APPAREL, OTHER	FOOD, BEVERAGE	PAPER, PRINTING	PRIMARY (METAL, NONMETALIC, PETRO/COAL)
8	PRIMARY (METAL, NONMETALIC, PETRO/COAL)	CHEMICALS, PLASTICS, RUBBER	FOOD, BEVERAGE	FURNITURE, APPAREL, OTHER
9	FOOD, BEVERAGE	PRIMARY (METAL, NONMETALIC, PETRO/COAL)	FURNITURE, APPAREL, OTHER	FOOD, BEVERAGE

Source: CMAP analysis, 2013.

Regional Manufacturing Industries

CMAP's scorecard illustrates how some industries are especially poised to be leaders in advanced manufacturing. This section uses the results of the scorecard to explore each of the region's nine core sectors, starting first with food and beverage manufacturing then working up the scorecard to the industries whose Product-Process-People scores most exhibit advanced manufacturing in the region.

How to Read the Individual Scorecard

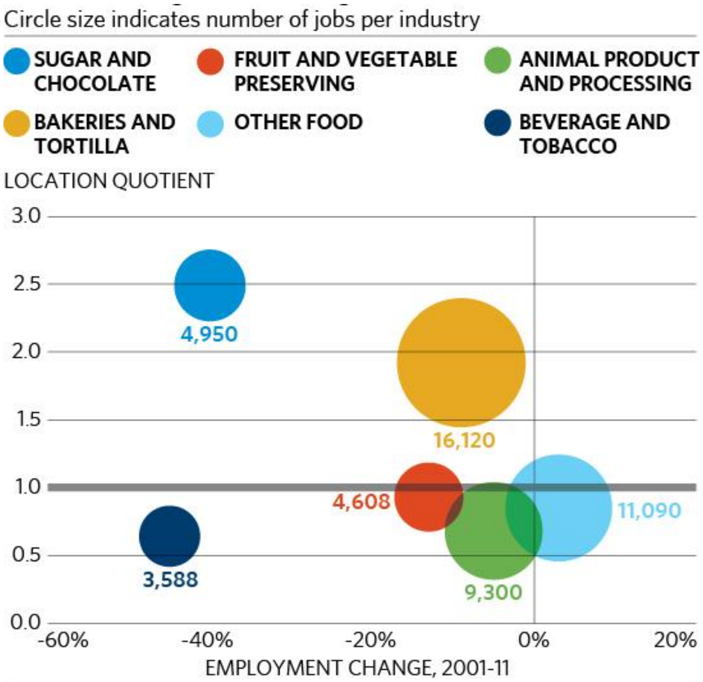
The individual advanced manufacturing scorecard displays the Product, Process, and People measures for each core sector along the spectrum of all manufacturing industries. Across manufacturing the Product indicator ranges from a "high" of one (since the Product indicator measures rank, a lower numerical value means a better score), to a low of nine, with the average at 4.5. The Process indicator arrays from a manufacturing high of 72 percent of value added to output to a low of 24 percent, with an average of 45 percent. And the People indicator has a high of $106,700, and average of $61,000, and a low of $46,749 (unlike the Process indicator, for both the Process and People indicators a higher numerical value means a more advanced score). In other words, the farther the left each score is on the spectrum, the better it measures on the advanced manufacturing scorecard. For example, the food and beverage scorecard above ranks nine out of the nine core sectors on the Product innovation index. With 44 percent of value added to output, food and beverage measures much closer to the manufacturing average, yet its wages puts it in the lower tier of the People indicator. The scorecard's black arrows highlight the individual scores. Arrow direction doesn't designate trends but is simply a visual tool to highlight the score. Finally, the left side of the individual scorecard provides the sector's LQ and current employment for reference.

Food and Beverage Manufacturing

A potato is an agricultural product. A potato chip, however, is a manufactured product. Firms in food and beverage manufacturing transform livestock, agriculture, and other raw materials into new products. At the heart of the Midwest's massive agricultural sector, the Chicago region has always played an important role in food manufacturing. Despite lower advanced manufacturing scores, food and beverage manufacturers may be insulated somewhat from excessive job loss because they produce primarily for the domestic market. For food in particular, domestic sources have "enormous inherent advantages over foreign producers. Freshness, shipping issues with perishables, local taste, and other factors are challenges to importers that are not easily or inexpensively overcome."[12] These unique factors make the industry less susceptible to offshoring.

[12] Michael Ettlinger and Kate Gordon, "The Importance and Promise of American Manufacturing," Center for American Progress, April 2011, p. 21.

Figure 6. Food and Beverage Manufacturing



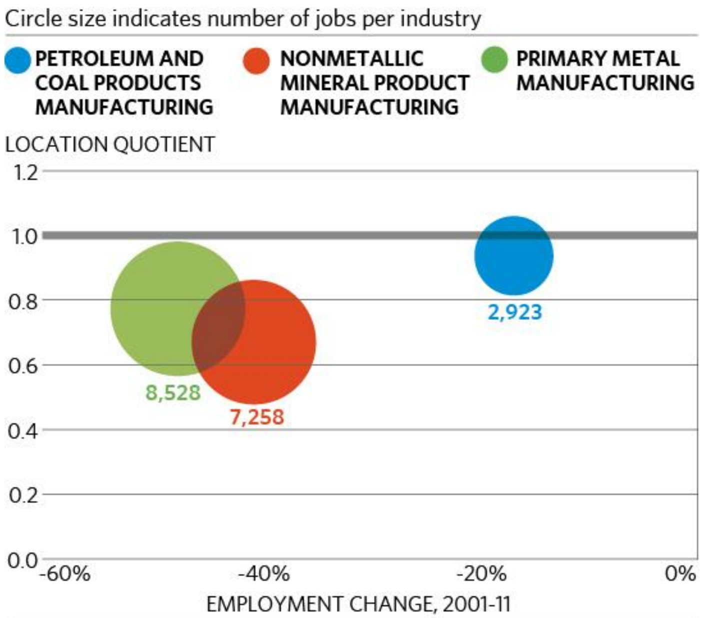
Source: CMAP analysis of EMSI data, 2012.

Furniture, Apparel, and Other Manufacturing

Metropolitan Chicago was once the nation's leading center for furniture and men's apparel manufacturing. Like other manufacturing industries such as meatpacking, paper, or printing however, the Chicago region has lost its foremost status. Not coincidentally, these industries are the same that perform the poorest on the advanced manufacturing scorecard. Furniture, apparel and other miscellaneous manufacturing had the second lowest position on the innovation index and the single lowest average wages, with value added slightly above average. Job loss in furniture, wood, apparel, and textiles has been particularly severe, falling 42 percent the past decade. The sector bubble chart of these industries has been combined with paper and printing.

Primary Metals, Minerals, and Petroleum

Figure 7. Primary Manufacturing



Source: CMAP analysis of EMSI data, 2012.

Primary manufacturing transforms raw materials such as stone, ore, coal, or crude petroleum into refined goods. Primary metal manufacturers use ore or scrap materials to smelt metals such as iron or steel and primary mineral manufacturers grind, heat, or shape minerals such as sand into products such as glass. Through the refining process, petroleum manufacturers convert crude petroleum into component products. Overall the Illinois portion of the Chicago region is less specialized in primary industries, though the greater tri-state area maintains one of the nation's leading primary metal centers (see sidebar).

Primary Metals in the Tri-State Region

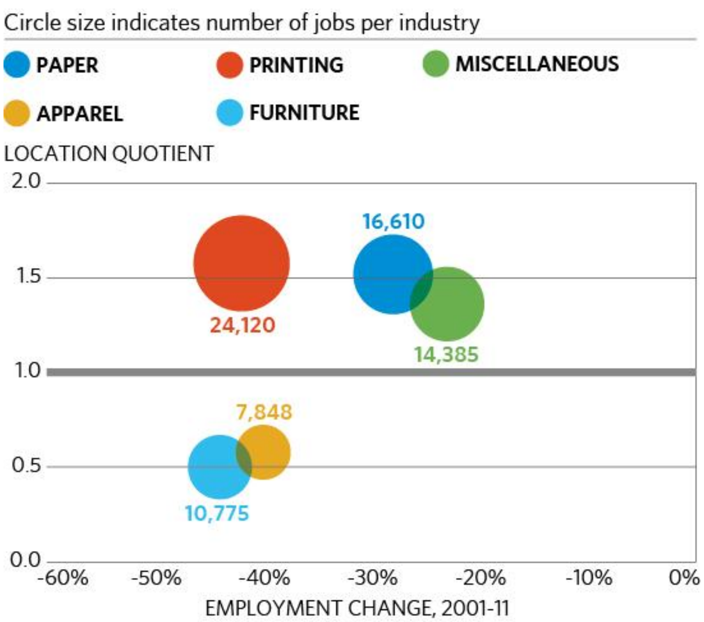
CMAP's cluster report focuses primarily on the seven Illinois counties of the Chicago region. The regional economy, however, is larger in scope to include parts of Indiana and Wisconsin. For the manufacturing cluster this includes the significant smelting and refining activity in northwestern Indiana. The LQ of primary metals and petroleum/coal manufacturing for the CMAP seven- county region both fall below one. The Chicago tri-state MSA however, has an LQ of 1.42 in petroleum/coal and 2.26 in primary metals. Put another way, there are about 8,000 primary metal jobs in the Illinois counties of the Chicago region but another 20,000 just across the state border in northwestern Indiana. As economies are fundamentally regional in scope, the manufacturing activities of the greater tri-state region serve a vital function in Chicago's regional cluster.

Paper and Printing

Historically the Chicago region has been one of the major centers of paper and printing manufacturing. The industry still employs over 40,000 workers in the region, though employment dropped almost 40 percent over the past decade. In this same period the region's degree of specialization also slipped.

Comprehensive data for the innovation index about paper and printing manufacturing were not available, so the industry did not receive a Product score on the advanced manufacturing scorecard. What data were available indicate the industry to be below average on innovation. For example, the industry was responsible for just a third of one percent of all utility patents in manufacturing in 2008, one of the lowest rates.[13] Below average wages also suggest the industry exhibits less of the characteristics of advanced manufacturing although firms do vary within the industry. Overall it seems that serious challenges remain for the industry, especially as e-readers and other digital devices continue to build market share.

Figure 8. Paper, Printing, and Miscellaneous Manufacturing



Source: CMAP analysis of EMSI data, 2012.

[13] Helper et al., February 2012, p. 37.

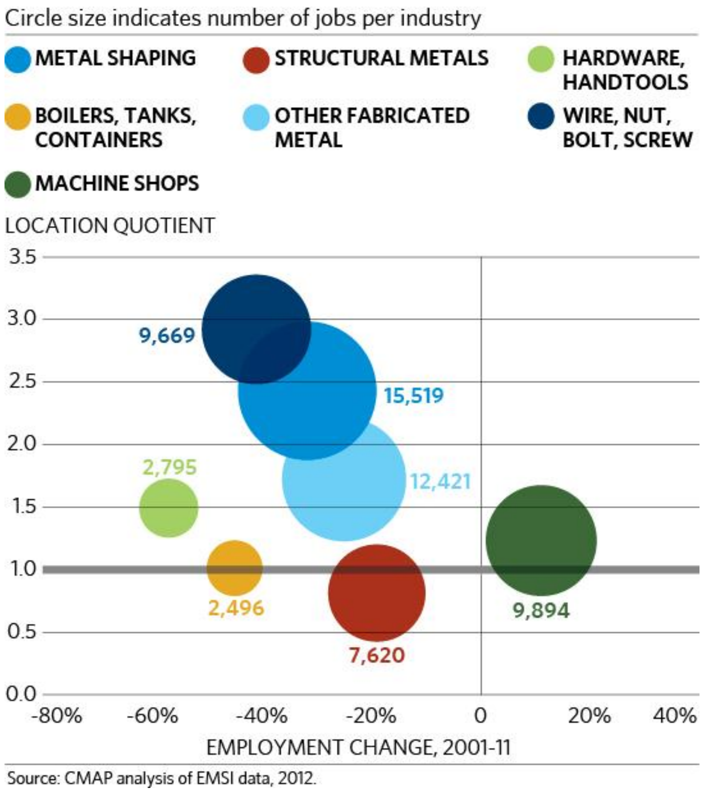
Fabricated Metals

The second largest sector of the region's major groupings, fabricated metal industries, transform metal into intermediate or end products for a wide variety of uses. Fabricated metal products include such diverse outputs as architectural and structural metals manufacturing, handtools, hardware, and cutlery manufacturing, and spring and wire manufacturing. Fabricated metal industries also shape metal though stamping, bending, and machining. Often fabricated metal manufacturers bid on customized jobs and, if awarded, build a customized intermediate product for use in other machinery.

With over 60,000 regional employees fabricated metals is a key strength of the regional economy. Of the nation's top ten metro areas, the Chicago region's LQ of 1.56 in fabricated metals is second only to the Houston region and outpaces other manufacturing centers such as Los Angeles.[14] The region is home to major firms such as Illinois Tool Works, as well as countless smaller shops working on a wide variety of machined parts. The sector remains interdependent on the region's other major sectors, especially machinery. As with machinery, fabricated metals added jobs this last year though employment is still down compared to the beginning of the decade. The following bubble chart shows the industries within the fabricated metal sector.

[14] CMAP analysis of U.S. Bureau of Labor Statistics data.

Figure 9. Fabricated Metal Manufacturing



Compared to machinery, the products produced by fabricated metalworking generally are less complex. The industry scores just below the manufacturing average on the Product and People indicators of the advanced manufacturing scorecard. Metal fabrication is a value-added process transforming raw and intermediate materials into more refined products, so the industry performs better on the Process indicator. Overall, fabricated metal manufacturing hovers around the advanced manufacturing average score.

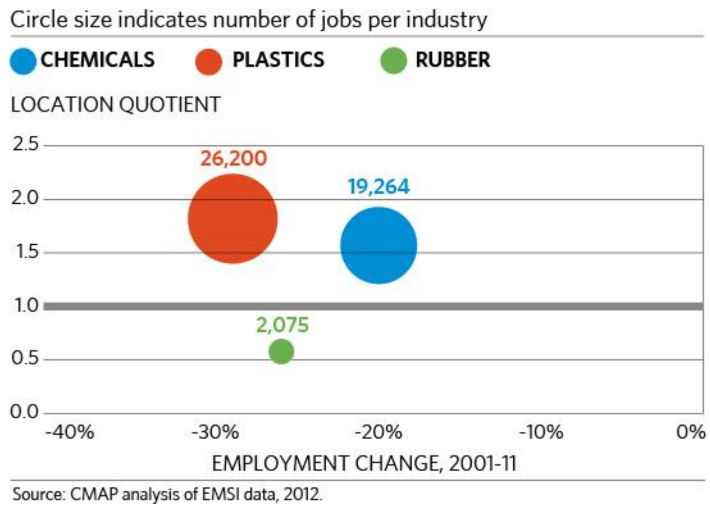
Drill-Down Industry: Machine Shops

Machine shops engage in metal fabrication primarily on a competitive order basis. These shops are generally lower volume, but highly customized to individual orders. As manufacturing becomes more and more complex, many firms find it easier to outsource to specialty shops instead of maintaining an in-house machining operation. Thus machine shops are a vital element of advanced manufacturing. In the Chicago region, machine shops are the only component of fabricated metals to grow employment this past decade. As the shift to customization (which is explored later in this report) continues, machine shops seemed well situated to build on this growth.

Chemicals, Plastics, Rubber

This sector consists of two major categories: firms manufacturing all types of chemicals except pharmaceuticals and those manufacturing plastic and rubber products. Chemicals rank higher on the scorecard, while rubber and plastics rank lower, so the overall grouping scores near the manufacturing average.

Figure 10. Chemicals, Plastics, Rubber Manufacturing



Chemical manufacturing encompasses a broad range of products such as paints, chlorine, dyes, pesticides, soaps, and petrochemicals. Chemical manufacturing may be less likely to move overseas compared to other manufacturing industries, because the risk of shipping often dangerous chemical products puts a premium on shorter distances to market. More recently, the supply chain disruption caused by natural disasters in Asia has given manufacturers pause about global sourcing of chemicals. Chemical manufacturing has a lower labor content, but the workers it employs need to be highly skilled.[15] These characteristics all lend themselves better to domestic manufacturing. Chemical manufacturing's job loss rate this past decade was much slower than the regional and national average. In the past ten years, the region's LQ grew from 1.49 to 1.57. Less specialized in pesticides and resins, the Chicago region concentrates in paints, soaps, and sanitary products.

Plastic products continue to be an important manufacturing output of the region. This past decade the region increased its specialization in the industry compared to the nation as a whole. Today the industry employs about 26,000 workers in the region, 82 percent more than would be expected compared to national employment distribution. As with all industries with a high LQ, this suggests that plastic manufacturing is a successful exporting industry. Rubber, in contrast, is a much smaller regional industry, with about 2,000 employed. Both rubber and plastic score slightly below average on the advanced manufacturing scorecard.

[15] Ettlinger and Gordon, 2011, p. 19.

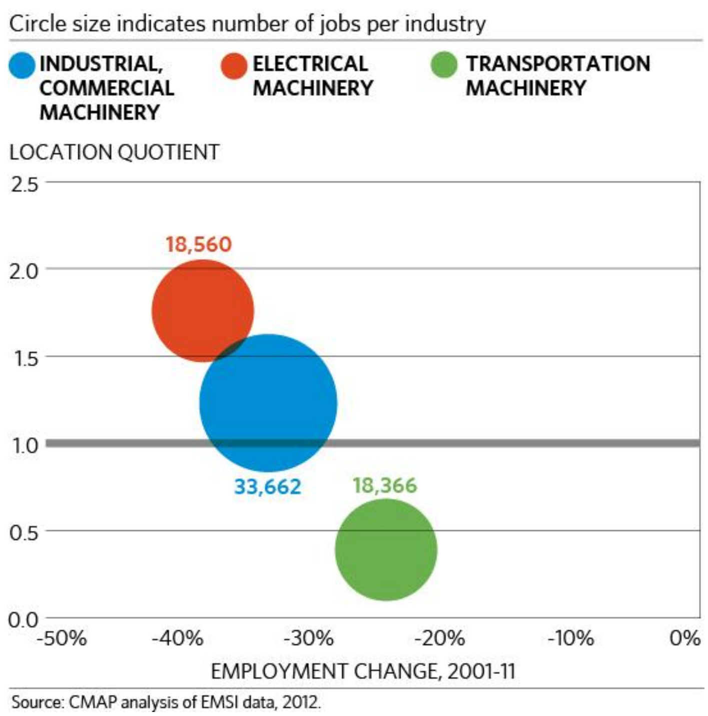
Machinery

Machinery is the region's largest manufacturing industry, with 70,582 employees in 2011. It includes transportation equipment manufacturing, appliances and electrical equipment machinery, and other industrial, commercial, agricultural, and construction machines. In general, individual machinery firms specialize in making very specific parts or machines: one firm may produce only washing machines, another just parts for a diesel engine, while another concentrates simply on electric light fixtures. Along with fabricated metals, machinery added about 3,000 jobs in 2011, helping power the region's first job increase in core manufacturing industries in over a decade.

Complex assembly and production techniques are a part of almost all machinery operations today while new products are constantly being introduced to capture market share. Machinery scores very high on the product measure and above average on both the Process and People components of the advanced manufacturing scorecard.

Overall, the region has an LQ of 0.88 in machinery, indicating less concentration compared to the national average. This is because the region under- specializes in transportation machinery (LQ of 0.37) compared to automotive or aerospace centers. Instead, metropolitan Chicago's machinery employment largely comes from concentrations in industrial and commercial machinery, and an even higher specialization in electrical machinery. Each of the three major machinery groupings is explored in turn.

Figure 11. Machinery Manufacturing



Transportation Machinery

Prioritizing strategies to support manufacturing requires an understanding of where the region has less expertise relative to other places. Unlike fellow Midwest manufacturing centers such as Detroit, Toledo, or Dayton, the Chicago region is under-specialized in the largest component of transportation equipment manufacturing: automotive. The region maintains a presence in tier suppliers but Ford's Chicago facility is the only automobile manufacturing plant left in the region; the addition of 1,200 employees to the plant beginning in 2010 is a positive sign, but a small addition compared to the size of the overall regional economy.

Drill-Down Industry: Rail Engine Manufacturing

Fifty percent of all the nation's rail traffic moves through the Chicago region. Supporting this impressive freight flow is a vibrant rail equipment manufacturing industry. In the past ten years regional employment producing engines, transmissions, and drive shafts for locomotives and other non-auto or aircraft use grew by eight percent. With a LQ of 1.87, the region is much more concentrated in this industry today than it was ten years ago. Major firms include Electro Motive Diesel, Inc., the world's largest diesel-electric locomotive manufacturer for commercial rail uses as well as National Railway Equipment Company. Moving forward the region has real potential to build on this strength, especially if fuel prices continue to rise and high-speed rail projects move forward.

Aerospace is the second major component of transportation equipment manufacturing. With less than 1,000 manufacturing jobs, the region is even less specialized in aerospace, though the region does maintain a strong presence in headquarter activities. Boeing, AAR, and Northstar Aerospace all have their headquarters in the region, though this entails different types of business activities than core production firms. Manufacturing clusters like aerospace in Seattle or automotive in Tennessee have established highly specialized transportation equipment supply chains and networks; the Chicago region would be hard-pressed to replicate these cluster-specific advantages. Instead of trying to out-compete other regions in their own competitive advantages, the Chicago region would be better served by focusing on its own specializations such as rail component manufacturing (see side bar).

The region is relatively stronger in the manufacturing of engines, transmissions, and other components for non-auto or aircraft use. As the rail capital of the country, much of this strength comes from rail manufacturing and the region has a long history in this industry dating back to the Pullman Company in the 1800s. The region does particularly well in locomotive engine manufacturing (see side bar). The region's rail manufacturing industry also typifies the advantages of cluster-based development as core manufacturing firms in the region maintain a dense network of suppliers, utilize a superior intermodal system, and are supported by specialized firms such as GE Capital Rail Services. The region's final product manufacturers can draw upon 15,425 specialized rail supply employees in the metropolitan area, one of the largest if not the largest concentration in the nation.[16]

[16] CMAP, "Metropolitan Chicago's Freight Cluster," 2012, p.70.

Electrical Machinery

While the Chicago region produces relatively less in automotive and aerospace manufacturing, it maintains a heavy specialization in electrical machinery manufacturing, evidenced by an LQ of 1.76. In other words, the region employs 76 percent more people than would be expected from the national average, a mammoth number for an economy as large as metropolitan Chicago. Despite this specialization, employment in electrical machinery manufacturing fell by nearly 40 percent in the past decade as international competition in appliances and other electrical machinery increased.

Drill-Down Industry: Turbine Manufacturing

Turbine manufacturing is particularly relevant because of the emergence of wind power as a clean energy alternative. Regional employment in turbine manufacturing grew from a mere 20 at the beginning of the decade to over 300 ten years later. Nordex, the German wind turbine giant, located their North American headquarters in Chicago. Likewise Xianjiang Goldwind -- one of the largest turbine companies in the world -- has its U.S. headquarters in the region. Though still quite small compared to other manufacturing industries, continued demand for alternative energy may promote growth in turbine manufacturing. At the heart of the nation's wind industry, metropolitan Chicago is poised to witness growth in this industry.

Industrial and Commercial Machinery

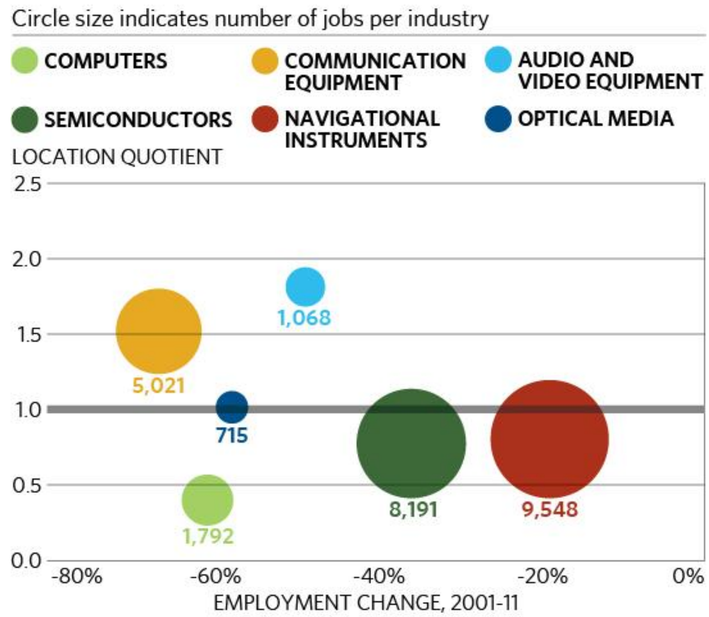
The final segment of machinery includes a broad range of machines for industrial and commercial use. As with electrical machinery, employment in this industry fell significantly over the past decade though the Chicago region has been able to maintain its high specialization even with employment loss. The strongest specialization of the segment is metalworking machinery, serving the region's concentration in fabricated metals.

Computers and Electronics

The computers/electronics and health sciences industries both score significantly higher on the scorecard compared to other industries, yet suggest different trajectories for advanced manufacturing in the Chicago region. While computers/electronics is one of the most technically advanced industries, the Chicago region is less specialized compared to the rest of the nation. About 10,000 regional workers are employed in computer and semiconductor manufacturing, a relatively small number compared to major centers such as Silicon Valley that maintain a strong computer cluster.

One area where the Chicago region traditionally has performed better is in communication equipment. Unfortunately, the region's specialization in this industry is quickly slipping. Employment in the industry that makes modems, routers, and switching equipment fell a staggering 75 percent the past decade while cell phone and other wireless communication equipment employment dropped 60 percent. Motorola -- started in Chicago in 1928 and one of the world's leading telecommunications firms -- experienced a tough decade, shedding employment and splitting into two independent companies. As the major telecommunications firm in the area, Motorola's difficulties have a disproportionate effect on the entire sector, though the telecomm company was not the only regional firm struggling.

Figure 12. Computer and Electronics Manufacturing



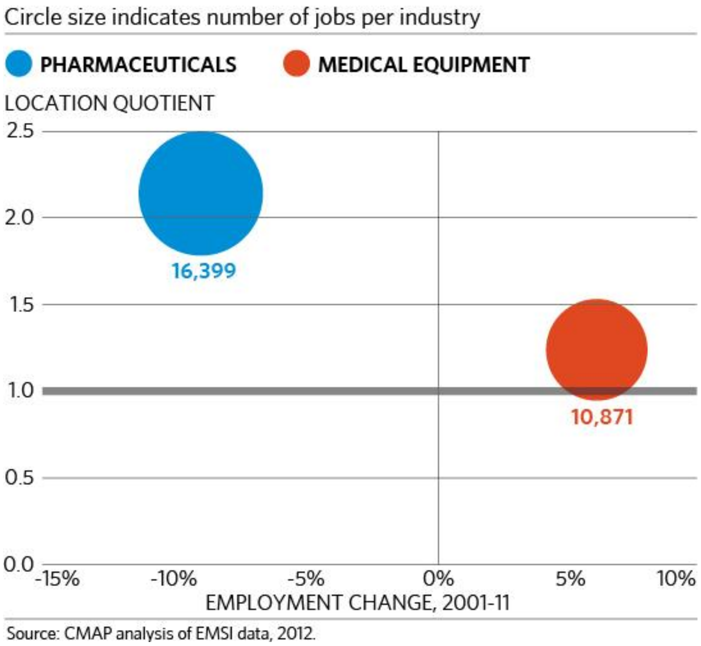
Source: CMAP analysis of EMSI data, 2012.

Electronic audio and video equipment such as amplifiers, stereo and speaker systems, and televisions exhibit more positive signs. Though job losses persist, the region is losing jobs in this specific industry at a much slower rate compared to the rest of the nation; the region has increased its specialization in this industry from an LQ of 1.48 to 1.81. Metropolitan Chicago also performs better on navigational equipment, an industry likely poised for growth as navigational devices are incorporated into an increasing number of products.

Health Sciences Manufacturing

While the region lacks a specialized cluster in computers, it contains a much stronger presence in the other industry scoring high on the advanced manufacturing scorecard: health sciences, which includes both pharmaceuticals and medical machinery manufacturing. The large-scale firm Abbott dominates the pharmaceutical industry in the region, while medical device manufacturing is spilt among many firms. Both pharmaceuticals and medical instrument manufacturing heavily concentrate in Lake County.

Figure 13. Health Sciences Manufacturing



Health sciences manufacturing had the highest score on both the value added and wage component of the advanced manufacturing scorecard. For the innovation index, pharmaceuticals ranked second highest behind computers (comprehensive data for medical equipment were not available).

In the past decade, health sciences manufacturing experienced the slowest job loss rate of any regional manufacturing industry, dipping four percent. Over the same timeframe, the region increased its concentration, with an LQ of 1.64 in 2011. The differing trajectories of computers/ electronics and health science manufacturing call attention to the second element of what will make manufacturing competitive in the 21st Century economy. In addition to performing well on the advanced manufacturing measures of Product, Process, and People, manufacturing in the Chicago region also needs to realize the advantages of cluster support in order to maintain competitiveness into the future. How clusters support advanced manufacturing is the topic of this report's next section.

Drill-Down Industry: Surgical Instruments Manufacturing

Surgical and other medical instrument manufacturing is one of the largest components of the region's health science manufacturing industry. While most manufacturing sectors have been shedding jobs, regional employment in this industry increased by a quarter over the past decade. Like other components of health science manufacturing, surgical instrument makers can draw on the region's large biotech cluster.

Supply, Support, Customer Industries of the Cluster

Core manufacturing industries do not operate in isolation but instead are linked to a regional network of suppliers, partners, investors, customers, and support networks. A cluster represents all these different elements of manufacturing's value chain. Taking a cluster approach to manufacturing also helps explain why the Chicago region has struggled in advanced industries such as computers or electronics but performed much better in health sciences or advanced machinery. Put simply, advanced manufacturing needs to be supported by cluster-specific advantages in order to be competitive in the contemporary global economy. This section illustrates the advantage of clustering for advanced manufacturing firms.

Why Advanced Manufacturing Needs Cluster Support

Firms across all industries gain advantages from clustering, and these advantages are even more amplified in advanced manufacturing. First, clustering gives manufacturing firms access to **specialized suppliers** with sufficient sophistication to meet the complex demands of advanced manufacturing supply chains. In a study on advanced manufacturing in New England, Deloitte called this supply chain network dynamic the "new competitive advantage" in manufacturing.[17] Second, clusters also grant firms access to a **specialized workforce** that is nimble and skilled enough to navigate the challenges of advanced manufacturing. Third, clustering connects manufacturers to **specialized customers**, facilitating the process of getting goods to market. Finally, clusters tend to **foster innovation** that is imperative to manufacturing's future productivity growth. A cluster's co-location of research, design, development, engineering, and manufacturing leads to the most innovative activity. This cross-fertilization of industry and academic subject experts fuels innovative ideas and modern manufacturing industries increasingly rely on multi-disciplinary interaction that only a large cluster such as Chicago can provide. Recent work from the Brookings Institution quantifies how important clustering advantages are to advanced manufacturing: 95 percent of all very high-technology manufacturing jobs in the nation are located in metropolitan areas.[18] Looking forward, the varied relationships supported by clusters will become even more intimate as new manufacturing technologies continue to be adopted.[19]

Direct Supply and Input Industries

Industries in the direct supply segment of the manufacturing cluster provide core firms with inputs and services necessary for production. Manufacturing industries transform raw materials like ore, crude petroleum, or agriculture into products like metals, plastics, and food. As such, the primary input for manufacturing industries is raw materials. Raw material extraction is not included in this cluster analysis however for two reasons. The first is that most of the extraction occurs outside the region and the second is that there is no feasible policy avenue to bring extraction to the region, as it is based on natural stores. The two inputs that are included for analysis are supply chain management and power generation/distribution.

Supply Chain Management

Supply chains play a paramount role in advanced manufacturing. In the past, much of manufacturing was vertically integrated, meaning the production process was centrally controlled from raw materials to final assembly. For example, Ford Motor Company's colossal River Rouge Complex turned raw materials into running vehicles under one single roof. Today, manufacturing -- and especially advanced manufacturing -- supply chains are much more dispersed. Continuing the automotive example, contemporary firms concentrate on highly specialized components of a finished vehicle; one firm may supply the engine, another the

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[17] Deloitte Consulting LLP, "Reexaming advanced manufacturing in a networked world: Prospects for a resurgence in New England," for the New England Council, December 2009, p. 17.

[18] Helper et al., April 2012, p.10.

[19] The Economist, "Factories and Jobs: Back to Making Stuff," Special Report on Manufacturing and Innovation, April 21, 2012; Helper et al., April 2012.

frame, and a third the tires to the final assembler. And these discrete parts manufacturers have their own subassembly of suppliers providing even further parts and subcomponents.

Organizing this flow of materials, subcomponents, and discrete parts demands increasing sophistication. Compounding this complexity, many firms today utilize a just-in-time production strategy where transfer windows become smaller and smaller. CMAP's freight cluster drill-down report describes these supply chain management trends in detail. Of note, the report recounts that over 75 percent of major companies now outsource their logistic activities to a third-party provider. Called 3PLs (third-party logistics providers) or freight transportation arrangement, these firms specialize in complex supply chain management. CMAP's freight cluster report describes how these 3PLs have emerged as a major competitive advantage of the regional economy, adopting new technologies and increasing in both employment and LQ over the past ten years.[20]

Many firms continue to control logistics in-house yet seek expertise in supply chain management. The second supply industry in the cluster is distribution and logistics consultants, who enable firms to maximize supply chain efficiencies. Like 3PLs, this industry is growing rapidly, increasing regional employment by over a third in the past decade. Supply chain management -- either through third party providers or consultant expertise -- is a key asset of metropolitan Chicago's manufacturing cluster and distinguishes the region from many other peer manufacturing centers.

Power Generation and Distribution

Manufacturing has been the largest domestic consumer of energy, at about one-third of total energy use.[21] In energy-intensive industries like petroleum refining, chemical manufacturing, or metal casting, the price of energy is a major factor of profitability. As the following table illustrates, manufacturing has the broadest range of energy inputs -- while commercial and residential receive most of their energy from electricity generation and transportation is almost entirely reliant on petroleum, manufacturing's balanced energy portfolio includes the highest percentage of coal yet also the highest utilization of renewables.

Manufacturing firms deciding where to site or expand production often consider the cost, availability, and reliability of electric and natural gas utilities as key locational decisions. In the future, renewable energy will likely play a more important role in firm's energy portfolios. As the price of different energy sources continues to fluctuate, access to broad energy production and distribution will remain a vital input for manufacturers.

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[20] CMAP's Freight Cluster Drill-Down can be accessed at http://www.cmap.illinois.gov/freight-drill-down.

[21] U.S. EPA, "Energy Trends in Selected Manufacturing Sectors," March 2007.

Table 5. National Energy Use in 2004 by Fuel Source

	Total Energy Use	Energy Use By Source				
		Electricity*	**Coal**	**Natural Gas**	**Petroleum**	**Renewables**
Manufacturing/ Industrial	35%	33.5%	6.5%	25.6%	29.4%	5%
Commercial	15%	76.2%	0.6%	18.2%	4.2%	0.8%
Residential	21%	66.8%	0.1%	23.6%	7.2%	2.3%
Transportation	29%	0.3%	0%	2.2%	96.5%	1%
	*Inputs for electricity production are 50% coal, 19% nuclear, 16% natural gas, 6% hydroelectric, and the remainder other renewables like solar or wind. Table taken from U.S. EPA, "Energy Trends in Selected Manufacturing Sectors," March 2007.					

Support Industries

Accounting for two thirds of all private R&D and 90 percent of all patents, manufacturing is the nation's largest source of innovation.[22] Supporting innovative product and process gains in the cluster's core are numerous research, design, and development firms. With over 100,000 jobs in the region, these R&D and design service firms are second only to core manufacturing as the most numerous in the cluster.

Research and Development

Despite the centrality of R&D to a healthy cluster, serious challenges persist in the Chicago region that if unaddressed will stifle future growth and the viability of advanced manufacturing in the region. The cluster's R&D firms are divided into two industries: testing laboratories, and broad R&D in engineering and the physical and life sciences (which support innovation across most manufacturing industries). While the region has performed well in testing laboratories -- adding employment and increasing its LQ in the past ten years -- overall the region is seriously underperforming in R&D compared to its historic strengths in this field.

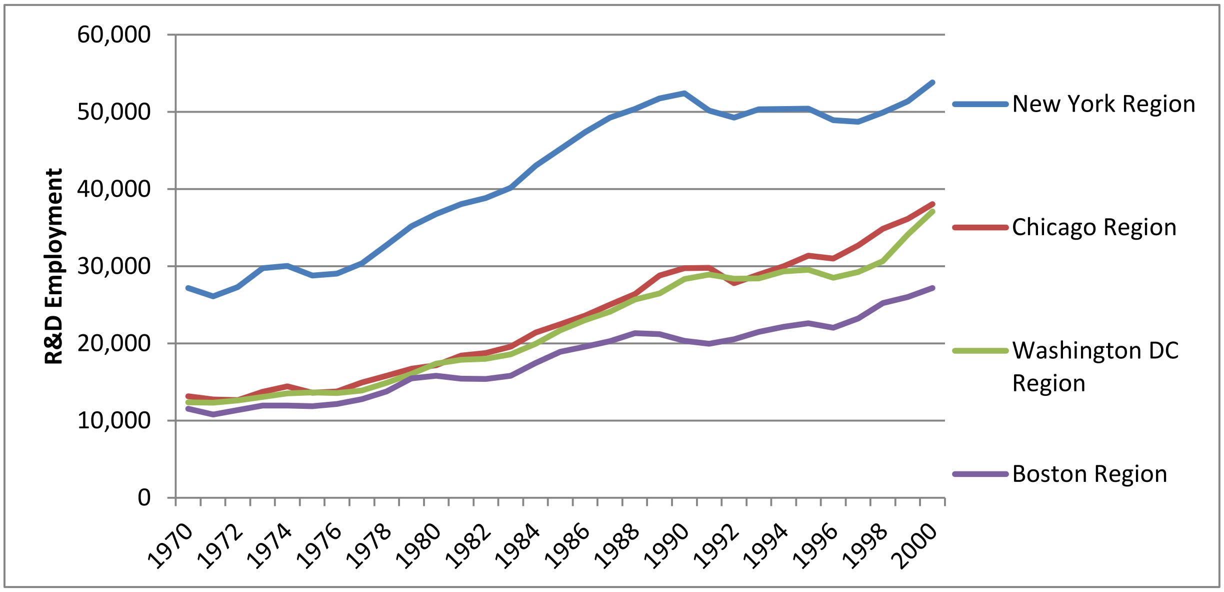
At the beginning of the decade the region was highly specialized in broad manufacturing R&D (LQ of 2.81). Within ten years however, the region has seen this strong point evaporate. By 2011, the region lost almost half of all R&D jobs; greater Chicago is now only slightly specialized in the broader R&D that supports manufacturing (LQ of 1.2). Metropolitan Chicago's recent underperformance in R&D deserves more attention. The downward trend is particularly disconcerting because it bucks the region's historic performance. As the following graph illustrates, the Chicago region added scientific R&D jobs[23] consistently between 1970 and 2000,

[22] Information Technology and Innovation Foundation, "The Case for a National Manufacturing Strategy," April 2011, p.13; White House, "A Framework for Revitalizing American Manufacturing," 2009.

[23] Scientific R&D includes research conducted in the social sciences and humanities as well as that in engineering and the physical and life sciences. Scientific R&D is used here because it is not possible to isolate the individual segments of R&D prior to 2000. Employment and gross regional product for social science and humanities research is relatively small and very consistent, so scientific R&D is a good proxy for the type of R&D needed to support manufacturing.

nearly tripling in size. In 2000, the region trailed only New York in scientific R&D employment and the contribution this research made to gross regional product.

Figure 14. Top Scientific R&D Regions: 1970-2000

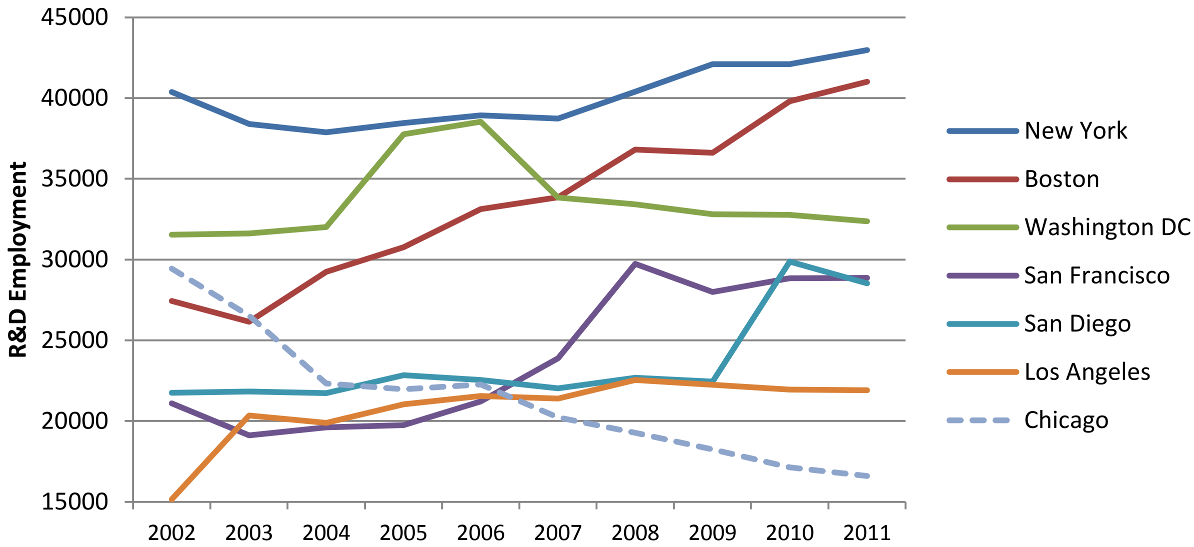


For the Chicago tri-state region.

Source: February 2012 Illinois Innovation Index.

Starting in 2000, the Chicago region's historic upwards trajectory in R&D flipped. What sets this apart from other job losses in the manufacturing cluster this past decade is that while metropolitan Chicago's R&D employment shrank, the country's other major innovation regions realized sustained R&D growth. So while the Chicago region was the second largest center for R&D in engineering, biotech, and the physical and life sciences in 2000, it has since been surpassed by the Boston, San Diego, Washington D.C., Los Angeles, San Francisco, and San Jose regions. The following graph visualizes how Chicago has not kept pace with its fellow innovative regions.

Figure 15. Manufacturing-Relevant R&D Employment 2002-2011



Source: CMAP analysis of Bureau of Labor Statistics (BLS) data, 2012.

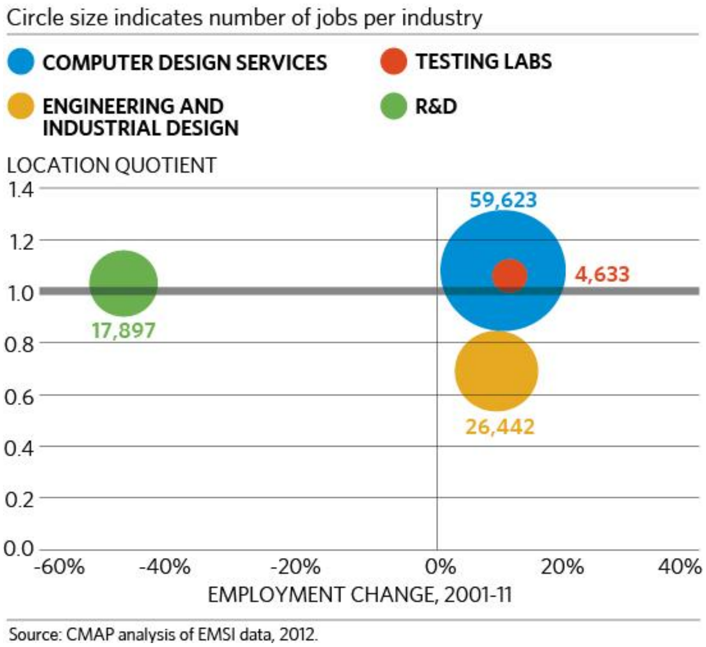
Note: 2011 data are preliminary release from BLS.

The innovation chapter of this report returns to the R&D challenge. It includes strategies for reversing the poor performance of the past decade to return the region to its historic position as an innovative leader.

Design Services

Industries in design services provide expertise in engineering, industrial design, computer related services, and other technical and scientific fields. Assignments undertaken by firms in this field can include consulting; technical services; preparation of plans, models, and designs; feasibility evaluations; and product optimization. The region is especially concentrated in the computer systems design services, employing close to 60,000 workers and adding over 5,000 jobs the past ten years. The regional economy also added jobs in engineering and industrial services.

Figure 16. Support Industries of the Manufacturing Cluster



Customer Industries

Manufacturing is an export-oriented industry, producing for regional, national, and even global markets. While final products are being shipped across the nation and globe, so too are discrete parts, intermediate goods, and many other components of manufacturing's long supply chain. All this movement of inputs and parts demands adequate transportation infrastructure as well as carriers to actually transport the materials. So while the ultimate customer of most manufactured goods will eventually be the end consumer, carriers are needed to move goods through the complex supply chain all the way from extraction to intermediate manufacturing to final market. This analysis defines customer industries as those freight carriers who enable exporting and supply chain movements.

While many supply chains stretch across the globe, the majority of manufactured goods movement is still regional. Specialized firms seek proximity to both up and downstream partners -- many try to be within a day's truck drive of major supply chain partners as a rule of thumb. U.S. Census Bureau data suggest that half of all manufactured goods movements by weight in the U.S. are less than 50 miles.[24] This number rises to 75 percent when the distance is expanded to 250 miles and suggests that even in the era of globalization, important elements of many supply chains are contained within metropolitan regions.[25]

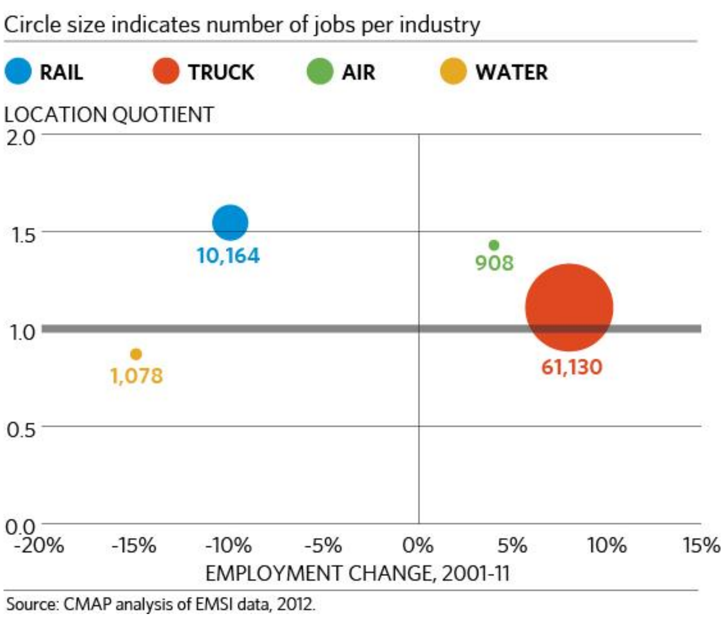
[24] U.S. Census Bureau, Annual Survey of Manufacturers, 2011.

[25] Manufactured product shipping distance varies starkly by industry and relates to the value of a good compared to its weight. For computers and electronics -- an industry with extremely high value compared to the weight of each unit shipped-- movements of less than 50 miles account for only 17 percent of total shipments. In contrast, 63 percent of all refined petroleum product moves occur within the same 50 mile boundary.

Metropolitan Chicago relies on freight carriers to move vast quantities of manufactured goods within the region. A hypothetical example helps illustrate how important freight carriers are to the cluster: ore from outside of the region is shipped to northwest Indiana and refined into a metal alloy. This alloy is then shipped to a fabricated metals shop in Addison to be stamped. The stamped metal next moves to a machine shop in Kane County to meet custom specifications from a sub-assembler in Chicago. The Chicago firm then sends its discrete part to an OEM (Original Equipment Manufacturer) in Des Plaines for final assembly. At each step in this example carriers move the good through the supply chain.

Even the most specialized regions will not meet all supply chain functions internally. Freight carriers play a crucial role in connecting firms to external suppliers. Continuing the example above, maybe no firm in the region had the capabilities of meeting the specifications of the sub-assembler in Chicago. The Chicago firm chooses instead to use the services of a machine shop in Cleveland, relying on carriers to bring the machined part into the region. Finally, freight carriers grant regional firms access to larger markets. In the above example, the final assembler in Des Plaines may sell some of his finished goods to the Chicago market, but also exports to Cincinnati and Charlotte, as well as China, Chile, and Canada.

Figure 17. Customer Industries of the Manufacturing Cluster



CMAP's freight cluster drill-down report details the vitality of freight carriers in the Chicago region. Between a quarter and a third of all freight moving in the United States passes through greater Chicago during some point of the move. The report shows how the region's specialization in intermodal moves grants the area a comparative advantage compared to other regions. Of the four freight carrier modes, trucking is by far the largest, and unlike other metro areas the Chicago region maintains a specialization in both local and long distance trucking. In the past ten years, the region added 7,500 trucking jobs, bucking national trends. For rail, the region's concentration is even greater, as half of all rail moves in the nation originate, terminate, or move through metropolitan Chicago. Air freight is a much smaller mode, but plays a vital role in moving high value goods quickly to market. The region's specialization in air freight buttresses its multimodal capability. Of all freight modes, only water is less represented in the Chicago region, though the greater tri-state area maintains some important facilities. To learn more about how freight carriers support the economic vibrancy of the region, see CMAP's freight cluster analysis at http://www.cmap.illinois.gov/freight-drill-down.

The Manufacturing Cluster's Connection to the Greater Regional Economy

This final section of this chapter describes how individual manufacturing industries connect to each other and how the manufacturing cluster in general relates to the overall regional economy. Using multiplier analysis, the section shows how expansion or contraction of core manufacturing industries has a profound ripple effect on the economy as a whole.

Multiplier Analysis

Multiplier analysis estimates the additional economic activity created when one industry expands. This analysis focuses on job multipliers to see how many additional jobs are supported by an increase of one job in manufacturing. A job multiplier of 1.5 suggests the increase of one job in a specific industry leads to an additional 0.5 jobs in the regional economy. Likewise, a job multiplier of three indicates that the creation of one job will support two additional jobs. Put simply, an industry with a higher multiplier has a greater ripple effect on the economy as a whole.

Compared to all other industries, manufacturing has the largest multiplier effect: a job increase in manufacturing supports sizable additional jobs in the overall economy. Economists differ on exactly how large the manufacturing job multiplier is (most estimates range from two to five additional jobs) but almost all agree that manufacturing's multiplier greatly surpasses any other segment of the economy.[26]

Using an input-output model developed by Economic Modeling Specialists Inc. (EMSI)[27], CMAP conducted a series of multiplier analyses on manufacturing industries in the region. EMSI's model is tailored to report on the Chicago region, so multiplier analysis is particularly important in gauging regional connectivity. As the results depict additional economic activity just for the Chicago region, the model helps suggest how many supported jobs fall within the region vs. those that leak outside the region.

The computer industry serves as an example of how less developed regional supply chains can dampen the force of a regional multiplier. Nationwide, computer manufacturing has one of the highest jobs multipliers, with a recent analysis suggesting that the most advanced computer manufacturing activities has a job multiplier of 16, meaning 15 other jobs are supported by an increase of one job in that industry.[28] CMAP's multiplier analysis for within the Chicago region

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[26] DeVol et al., 2009; Information Technology and Innovation Foundation, "The Case for a National Manufacturing Strategy," April 2011.

[27] EMSI's input-output model is built to stimulate the effects of industry expansion or contraction on other industries in the region. It reports on single industries as well as industry clusters.

[28] Information Technology and Innovation Foundation, "The Case for a National Manufacturing Strategy," April 2011, p.12.

suggests that adding a position in computer manufacturing would add only a single additional job to the regional economy, while the other 14 positions would fall outside of the regional economy. In other words, though computer manufacturing has a high multiplier overall, it leaks out of the region to areas with more developed computer clusters. Computers may be an extreme example, given the industry is under intense international competitive pressure. Yet it also illustrates that advanced manufacturing benefits from a robust cluster. While the industry ranks high on the advanced manufacturing scorecard, the Chicago region doesn't have as strongly developed internal supply chains, helping explain poorer industry performance this past decade.

In contrast to the computers example, multipliers from machinery and health sciences -- the other top industries on the advanced manufacturing scorecard -- show how much more of the ripple effects of expansion in these industries would be felt within the region. The graphic on the following page visualizes the multiplier effect of rail engine manufacturing. The following call out box compares this regional industry to surgical equipment manufacturing to show how individual industries connect to different parts of the regional economy.

Rail Engines and Surgical Supplies

Rail engines and surgical supply manufacturing are two strengths of the regional cluster. Rail engine manufacturing has an estimated regional job multiplier of 5.07, while for surgical supplies it is 3.56. Though an expansion in each industry supports substantial jobs within the region, they target different segments of the economy.

For rail engines much of the job increase would be realized in other core manufacturing firms, especially in machinery, fabricated metals, and primary metals. Surgical equipment would support fewer core manufacturing jobs, mainly in plastics and fabricated metals. The expansion however would lead to more R&D activity, calling attention to the research intensity of the health sciences.

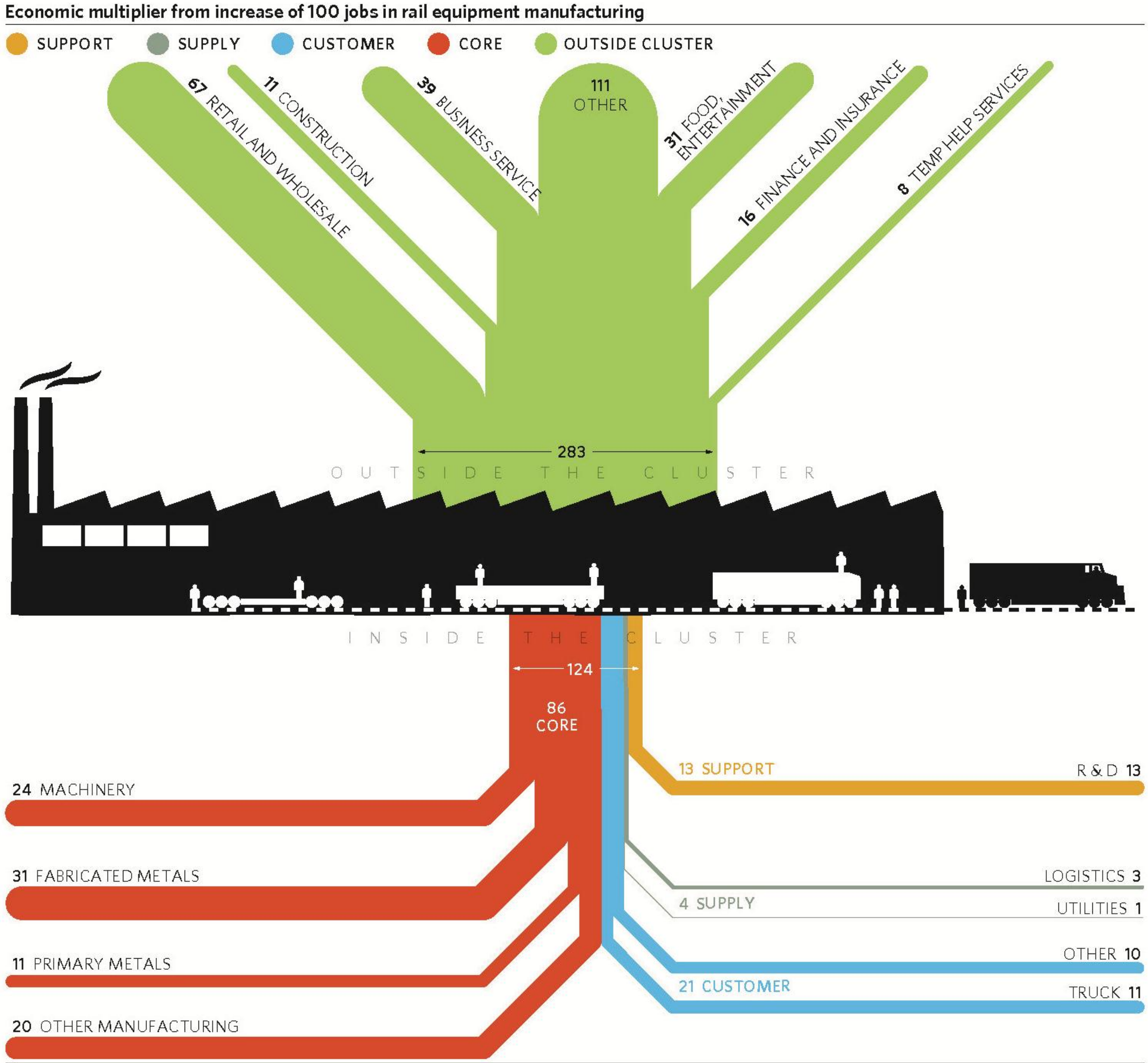
Results of Multiplier Analysis

	Rail Engine Manufacturers	Surgical Instrument Manufacturers
Percent of additional jobs created in core manufacturing firms	21%	8%
Percent of additional jobs created in R&D	3%	6%

Source: CMAP analysis, EMSI.

Multiplier analysis shows how manufacturing expansion supports economic activity not only within the cluster but in the overall economy as well. Industries such as wholesale or retail trade as well as construction are particularly tied to the vibrancy of the manufacturing cluster. Results of the model show that expansion in manufacturing employment also leads to an uptake in recreation, food, entertainment, and associated positions as new manufacturing workers (who earn a quarter more than the regional average) become consumers in the regional economy. Finally, manufacturing expansion has a substantial influence on business services, as production firms increasingly come to rely on these services to complement their core competencies in manufacturing.

Figure 18. Employment Increase in Rail Engine Manufacturing Supports Jobs in Entire Regional Economy



Source: CMAP Analysis of EMSI Input-Output Model, 2012.

This chart depicts the regional ripple effects from an expansion of 100 jobs in the rail engine manufacturing industry. This increase in jobs would support an additional 407 jobs in the region, with 124 of these inside the cluster (depicted in the above graphic in red, blue, and yellow) and 283 outside the cluster (shown in green). Many of the additional jobs within the cluster flow to primary metals, fabricated metals, and other machinery, suggesting the region has the capacity to meet much of the metalworking supply chain internally.

Chapter 2: International and National Developments

Historically, a robust manufacturing cluster has driven the economic prosperity of metropolitan Chicago, and the nation as a whole has benefitted greatly over the last century from the ingenuity and products that have emerged here. While the first chapter described the cluster's major industries, this chapter explores how manufacturing came to be a central part of our economy. The region's strong manufacturing foundation has enabled metropolitan Chicago to adapt in the face of ever-changing domestic and international pressures. As our world becomes more interconnected, metropolitan Chicago faces a host of serious new challenges. Implementing the right mix of private and public solutions may hold the key to whether metropolitan Chicago can maintain its position as a global economic center in the 21st Century.

Chapter 2 is a brief overview of the history of manufacturing in metropolitan Chicago and the Midwest, highlighting its specific role within the larger domestic and international contexts. Specific attention is paid to recent changes over the last decade and the large manufacturing job losses experienced in metropolitan Chicago and elsewhere in the U.S. Chapter 3 will then cover the range of specific challenges and opportunities for our region across the areas of infrastructure, innovation, and workforce.

Rise of Manufacturing in Metropolitan Chicago and the Greater Midwest

Manufacturing in the Chicago region and greater Midwest helped propel the U.S. to its position as the world's most productive, dynamic, and powerful economy. While the industrial revolution began years before in Europe, by the turn of the 20th Century, entrepreneurs across diverse industries had flocked to the Midwest and specifically Chicago to take advantage of available land, plentiful labor, and access to the nation's transportation hub. These assets played a fundamental role in building a strong manufacturing base and supported the growth of a diverse economy. A growing higher education system provided the engineers and scientists needed to run and grow industries. Migration and immigration ensured that factories had the workers they needed on the factory floor producing steel, building machinery, or packaging goods.

As people moved westward throughout the 19th Century, Chicago became the nation's railroad hub, connecting the Pacific to the Atlantic. The railroads, which linked to area water ports,[29] provided reliable year-round transport, and were so important that farmers and rural towns helped finance construction of some lines so that they could transport livestock to Chicago's stockyards and grain to east coast markets and burgeoning cities like Detroit, Cleveland, Kansas City, St. Paul, Omaha, Cincinnati, and St. Louis.[30]

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[29] Richard Stewart, Great Lakes Transportation System, 2006, p. 1.

[30] Ibid.

While rail, roadways, and canals were critical for the Midwest's long-term growth, it was the people who solved problems, developed new manufacturing techniques, and kept factories running, which allowed Chicago and the Midwest to sustain growth and innovation in manufacturing. The federal government's earlier investments in education -- especially land-grant universities -- made higher education more affordable and more accessible throughout the Midwest. These universities, which included the University of Illinois Urbana-Champaign, Purdue University, Michigan State University, University of Wisconsin-Madison, and Iowa State University,[31] emerged as critical assets for the growing industries that required more skilled workers to run factories and develop ideas for more advanced products.

A large and growing supply of immigrant laborers also helped to build metropolitan Chicago's manufacturing cluster. Chicago and the greater Midwest were leading destinations for immigrants. By 1890, 79 percent of Chicagoans were foreign-born or first-generation.[32] Immigrant labor dominated industries from iron and steel, meatpacking, clothing and garment industry, printing, and electrical machinery.[33]

Additionally, rural-to-urban migration in the Midwest started in the 19th Century and directly coincided with industrialization.[34] When industrial development expanded rapidly at the start of the 20th Century, African American migrants from the South came to Chicago by the hundreds of thousands.[35] This rapid population growth not only provided a supply of workers, but also grew the demand for manufactured goods.

Early Planned Manufacturing Districts

In 1905, an entrepreneur and investor created the first planned manufacturing district in the United States.[36] Located in Chicago's near west side, the district served as a private banker, business incubator, and maintenance operator. By 1915, over 40,000 people were employed in the district and similar industrial parks were established across the region trying to replicate the network of front office, research, and production facilities in close proximity.[37]

Unlike the already dense Northeast, the Midwest also offered ample space for development, ideal for Chicago's early heavy, land-intensive industries like steel and machinery. Chicago's

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[31] William Cronon, *Nature's Metropolis,* W.W. Norton & Co, 1991.

[32] Rachel Nugent, "Demographics," Encyclopedia of Chicago, 2005. The author notes, "One on top of another, European peoples tumbled in [to Chicago], starting with Irish in the 1840s, quickly followed by Germans, British, and Scandinavians; then, overlapping with them, Czechs, Lithuanians, Serbs, Croats, Greeks, and Chinese; and recently, Mexicans, Caribbeans, and a broad-sourced array of Central Americans and Asians, along with a new (and smaller) wave of Eastern Europeans."

[33] Library of Congress, "America at Work: Topics of Work," June 1, 2000.

[34] Richard Steckel, "Household Migration, Urban Growth and Industrialization," National Bureau of Economic Research, Boston, 1987, p.1.

[35] Nugent, 2005.

[36] Charles Stockwell, "Central manufacturing District," Encyclopedia of Chicago, 2005.

[37] Ibid.

water access was also vital for manufacturing processes and for the movements of goods. The 570-acre U.S. Steel South Works plant founded in the late 19th Century at the mouth of the Calumet River on Lake Michigan was one such example. Its location along the lake also offered another advantage -- the steel mill was able to pour the slag, the byproduct of steel production, into the lake to form additional land as needed.[38] Further south, the 100-acre Western Steel Car & Foundry Company was using steel to produce 100 railroad cars in Hegewisch by 1905.[39] Around the same time, the region also developed the first planned manufacturing district.

By the turn of the 20th Century, Chicago had become one of the nation's largest and most diverse manufacturing hubs. Rather than concentrate on a single or few industries, Chicago's factories were producing a very wide variety of products from primary metals, to food, medicine, furniture, textiles, and electronics. The overall scale of manufacturing grew exponentially during this time. In 1900, the nation had only 14 firms that employed more than 6,000 workers, with all three of the large Midwestern factories located in Chicago. By 1915, there were over 50 such mega-factories in the Midwest producing half of the manufactured goods in the United States.[40]

Chicago's manufacturing quickly became regional in scale. In fact, the share of manufacturing employment in the 1920s declined in the City of Chicago relative to industrial suburbs like Hammond and Cicero.[41] Factories did not simply move out of the city. One study of 1,000 companies found that between 1923 and 1929 that 26 percent of the factories surveyed moved but 52 percent either expanded or built new factories.[42] Chicago was particularly hard hit by the Great Depression with only 50 percent of the people employed in manufacturing in 1927 still working in the sector by 1933.[43]

War-Time Economy

World War II transformed the scale of American manufacturing. Chicago became a focal point of a national research, development, and production agenda, yielding technological advances applicable not only to defense but also civilian use for many years to come. During this period, the U.S. gross national product surged by more than 50 percent, while Europe's fell by 25 percent.[44] Unlike its counterparts in Europe or Japan, U.S. post-war manufacturing remained intact, and by 1950, American manufacturing companies were producing 60 percent of the world's manufacturing goods.[45] Growth in Midwestern industry was supported by ample

[38] Kaplan, Jacob. *South Works.* Forgotten Chicago. December 2008.

[39] Sellers, Rod et al. *Chicago's Southeast Side: An Environmental History*. Chicago Metro History Education Center. 1997.

[40] David Moberg, "Work," Encyclopedia of Chicago, 2005.

[41] Lewis, Robert, *Chicago Made: Factory Networks in the Industrial Metropolis.* University of Chicago Press, 2008.

[42] Ibid.

[43] Tracey Deutsch, "Great Depression," Encyclopedia of Chicago, 2005.

[44] Paul Kennedy, *The Rise and Fall of the Great Powers*, Fontana Press, London, 1989, p. 219

[45] William Branson, "Trends in United States International Trade and Investment Since World War II," *The American Economy in Transition*, Martin Feldstein, ed, University of Chicago Press, Chicago, 1980, p. 184

access to rich natural resources like fertile soil for food production, raw materials like iron ore, and fossil fuels for energy.

The region's diversified industrial base produced over $24 billion in wartime goods, leading the nation through a phenomenal period of growth.[46] Approximately 60 electronics manufacturers in the Chicago region produced over half of the electronics used by the military during the war.[47] Motorola made the first walkie-talkie.[48] The Dodge-Chicago plant, occupying 30 city blocks on Chicago's south side, was the only plant in the country converting raw materials, like pig iron and aluminum and turning out B-29 bomber engines at the other end.[49]

This was also a period of advancement in medical sciences. Baxter International was the only company in the world making the equipment that made blood storage and transfusions possible.[50] Abbott Laboratories was the first manufacturer to develop large-scale production of penicillin.[51] The region's food manufacturers also responded to war-time food rations and provided quick-fix foods for women working out of the home. For example, Kraft Foods' Mac and Cheese dinner provided families with a meatless dinner option that did not require a great deal of rationed milk to prepare.[52] These examples illustrate a history of the region's manufacturers innovating in order to address new markets and resolve new challenges.

The region significantly expanded its capacity to conduct R&D during the war. With the University of Chicago at the center of nuclear technology, the region became one of the focal points for national research. To continue this work two national laboratories, Argonne (1946) and later Fermilab (1967) were established to conduct basic research in areas like energy. Private companies were also pushed to innovate during the war to respond to the extremely high levels of demand.

During the war, many factories ran twenty-four hours a day, a scale of operation only made possible by a large and capable workforce. To train this workforce, a robust network of job training programs was established in public high schools, technical education centers and universities. Classes focused on machining, welding, and other essential manufacturing skills ran in three shifts around the clock.[53] A generation of thousands of skilled machinists, welders, and other trades workers was trained during this period. The rapid scaling up of Chicago's industries also meant thousands of jobs became available for able-bodied migrants willing to

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[46] Perry Duis, "No Time for Pricacy: World War II and Chicago's Families," *War in American Culture: Society and Consciousness in World War II,* S. H. Lewis Erinberg, ed., University of Chicago Press, Chicago, 1996, pp. 17-45.

[47] Richard Easterlin, "Internal Migration and the Spatial distribution of Population," *Growth and Composition of the American Population in the Twentieth Century,* Cambridge University Press, 2008.

[48] "A Legacy of Innovation: Timeline of Motorola History Since 1928," Motorola Solutions Inc, 2012.

[49] "Chrysler Goes to War," Walter P. Chrysler Museum, 2009, p. 5.

[50] "History," Baxter International Laboratories, 2012.

[51] "Discovery and Development of Penicillin," American Chemical Society, Washington DC, 1999.

[52] Jesse Rhodes, *Food & Think,* Smithsonian Magazine Blog, March 22, 2011.

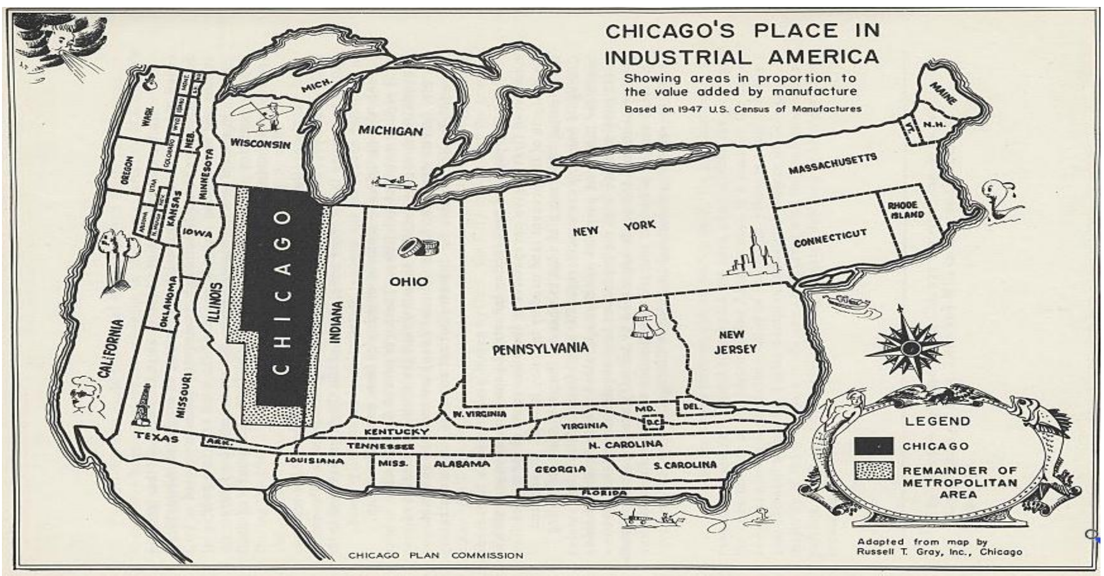
[53] Branson, 1980, p. 184.

work hard. The call was answered by tens of thousands of African Americans who were looking for opportunities to leave the agricultural south.[54]

Post-War Boom

After the war, the United States was the only large economy with its manufacturing industry still fully intact. Much of Europe and Japan's manufacturing infrastructure had been crippled with many manufacturing hubs destroyed by bombings and fire.[55] Japan, for instance, lost 40 percent of its industrial plants and infrastructure. On the other hand, American manufacturers maintained high capacity within an economy that had regained stability during the war. By 1950, nearly one-third of non-agricultural workers were employed in manufacturing. Investments made during the war in research and technology development, in workforce training, in expanding factories, and in the infrastructure to quickly move those products to where they are needed paved the way for the post-war boom.

Figure 19: Chicago's Place in Mid-20th Century Industrial America



Source: Encyclopedia of Chicago.[56]

The Chicago Plan Commission used the 1947 U.S. Census of Manufacturers to develop this graphical depiction of the magnitude of Chicago's manufacturing, using value added to scale relative contributions of states' manufacturing sectors across the country.

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[54] Duis, 1996.

[55] Branislav Slantchev, "Strategic Bombing in World War II," *Strategy in the Missile Age,* Bernard Brodie, ed, Princeton University Press, Princeton, 1965, p. 127.

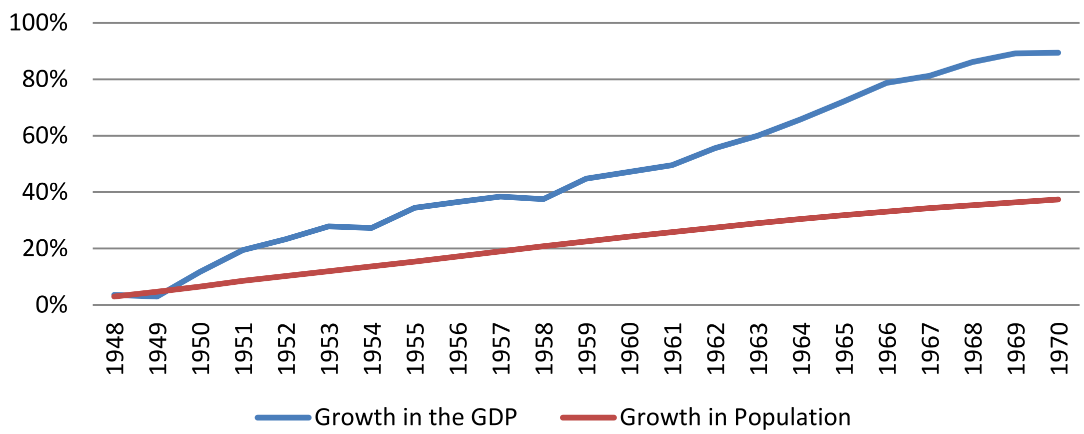
[56] Richard Gary, *Chicago's Place in Industrial America*, Chicago Plan Commission, 1952.

Many of the manufacturing and product advances developed for the war were put to use for civilian purposes. Factories like Ford and Chrysler and their suppliers in the Chicago region that had produced airplanes around the clock changed their lines to resume production of cars. Pharmaceutical companies continued their production and research on new drugs, like antibiotics, for the civilian population. After the war, Baxter laboratories moved beyond its production of blood transfusion devices to produce the first kidney dialysis machine.

This was an era of rapid expansion -- the U.S. quickly grew to become the world's largest and strongest economy -- its productivity, scale, ingenuity, products, and skilled workforce was unparalleled. By 1956, American companies were producing 60 percent of the world's manufactured goods.[57] In the 25 year period after the war, the nation's population grew nearly 40 percent while the Gross Domestic Product (GDP) grew almost 90 percent.[58]

During this time, workers could enter manufacturing occupations with little more than a high school diploma and turn the job into a life-long career. These trade workers were able to support a family and a middle-class lifestyle where their children would have higher educational outcomes than the generations before them.[59] Manufacturing workers in the Chicago region enjoyed relatively high wages -- industrial wages were closest to white-collar wages during this period[60] -- which enabled workers to purchase homes, cars, and many other sought after conveniences of the middle class. Demand for these goods outpaced domestic production and foreign producers began to enter the market to meet those needs.

Figure 20: Post World War II Change in GDP and Population



Sources: U.S. Bureau of Economic Analysis, U.S. Census, and CMAP analysis.

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[57] Branson, 1980, p. 184.

[58] U.S. Census and Bureau of Labor Statistics.

[59] Carlos Cardoso, "Business Forum: Regaining American Dream starts with a Prosperous Manufacturing Middle Class," Pittsburgh Post-Gazette, July 2, 2012.

[60] Claudia Goldin & Robert Margo, *The Great Compression: The Wage Structure in the United States at Mid-Century*, National Bureau of Economic Research, 1991.

In conjunction with economic growth, the population became more mobile. After 1950, vehicle ownership per capita increased by almost two percent per year and the federal government began building a vast network of over 40,000 miles of interstate highways.[61] In 1956, containerized shipping was invented and patented by the one of the largest trucking companies in the nation.[62] This made an everlasting impact on the location of manufacturing and freight movements. As population began to shift towards the Sun Belt regions, so did growth in jobs.[63] After the Great Depression Sun Belt growth was concentrated in southern states of Georgia, Mississippi, Alabama, Louisiana, and on the west coast in California.[64]

Rising Competition

By the late 1970s, the Midwest's dominance began to fade as manufacturers around the world and in other parts of the U.S. developed strong manufacturing sectors. Japan and European countries spent 30 years after the war rebuilding their roads, rail, and ports and reviving factories.[65] Their reconstruction and strategic investments in industry paid off, and as a result Midwestern legacy industries like steel, electronics, and automotive began to struggle to compete with lower cost and higher quality producers. The U.S. enjoyed several decades of overall GDP growth, but while strong, its growth rate was still outpaced by Japan, Canada, France, Germany, and Italy during the 1960s and 1970s.[66] While the U.S. economy remained considerably larger than any of those countries, these nations began to catch up and compete with American industry.

As other countries around the world expanded their manufacturing clusters, they developed their own approaches and techniques to grow these industries. Germany's unique universal banking system was designed to make financing readily available to industry and is credited in part with the country's rapid industrial development. [67] Germany also had a highly skilled workforce prepared by an extensive system of technical universities training engineers and managers for industry and trained factory workers through an education system that incorporated apprenticeships with academic training. [68] Many German factories were vertically integrated and production was organized into geographic regions that supported specialization.

[61] Federal Highway Administration, "Dwight D. Eisenhower National System of Interstate and Defense Highways," U.S. Department of Transportation, 2012.

[62] "All About Shipping Containers," Intermodal Steel Building Units Association, 2012.

[63] The Sun Belt regions generally include states below the 36th parallel, north latitude. After the 1970s, growth shifted to Texas and the Southwest states of Arizona and New Mexico.

[64] Edward Glaser and Kristina Tobio, *The Rise of the Sunbelt*, Harvard University Taubman Center Political Briefs, May 2007.

[65] Ronald Dolan and Robert Worden, eds. *Japan: A Country Study*, Library of Congress, Washington DC, 1994.

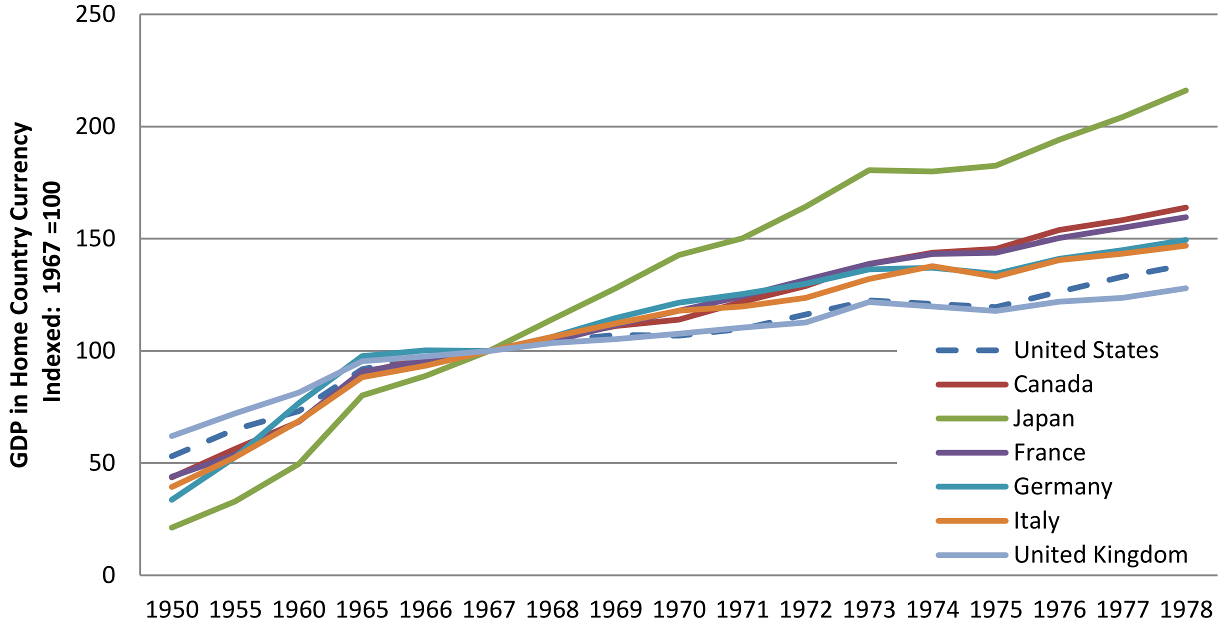
[66] U.S. Bureau of Labor Statistics.

[67] Buschgen, H.E., "The Universal Banking System in the Federal Republic of Germany," Journal of Cmparative Corporate Law and Securities Regulation, 1979.

[68] Herrigel, Gary, *Industrial Constructions: The Sources of German Industrial Power*, Cambridge University Press, 1996, p. 114.

Though Germany had the largest industrial base, Italy, France, and Great Britain all had sizable manufacturing sectors producing a variety of goods, from textiles, furniture, automobiles, chemicals to aircraft, satisfying more of their domestic economies' demands and producing goods for export. [69]

Figure 21. Index of Real GDP



Source: U.S. Department of Labor and analysis by Branson, Giersch, and Peterson.[70]

Note: This index compares growth in GDP using each country's own currency, using 1967 as the base year.

Japan's rise struck Chicago and the Midwest particularly hard, especially in the sectors of steel, electronics, machine tools, chemicals, and automobiles. Japanese industries quickly rebuilt capacity in electric power, coal, iron, and steel.[71] They also rebuilt their infrastructure of industrialization like factories and shipyards, much of which the government had originally subsidized or built in the first place.[72] The Japanese government also made direct investments in capital equipment, increasing its levels of supports each decade from the 1960s to the 1980s. In turn, industries were able to focus on R&D and devising effective production processes.[73] According to U.S. Bureau of Labor Statistics (BLS) data, Japanese manufacturing workforce were paid at least 50 percent less than American workers on average until the mid-1980s.[74] At

[69] Thomas Zeiler, *American Trade & Power in the 1960s*, Columbia University Press, 1992, p. 148.

[70] Branson, 1980, p. 187.

[71] Dolan and Worden, 1994.

[72] Ibid.

[73] Ibid.

[74] U.S. Bureau of Labor Statistics, *International Comparisons of Hourly Compensation Costs in Manufacturing*, 2010.

the same time, Japanese models of lean, low-waste, low-inventory production incorporated high standards for production quality. The impacts of these strategies were felt for years in Chicago's economy among manufactures like electronics or automotive suppliers.

By the 1980s, the global marketplace had evolved to become a much more connected place, due largely to significant advances in the freight cluster and telecommunications, which allowed people and businesses around the world to communicate quickly and reliably. Computers with data storage and accounting capabilities enabled companies to keep track of increasingly complex supply-chains and businesses became less constrained by geography and gained accesses to markets around the globe. Many manufacturers in Chicago and the Midwest could not compete with the imported goods, like radios and televisions, which caused area firms to shrink or fold.[75]

Domestic competition was also changing the internal landscape of American manufacturing. Chicago and the Midwest began to lose growth to the Sunbelt regions in the South, Southwest and West Coast. Because the South had remained largely agricultural until the middle of the 20th Century[76] -- unlike its industrialized neighbors to the north -- manufacturers found an ample supply of land open for development, as they had half a century earlier in the Midwest.

Supporting Manufacturing in Alabama

As manufacturing spread throughout the nation, industry grew particularly quickly in Sunbelt States. Some states were able to attract manufacturers by heavily leveraging assets like less expensive and available land, governmental support for growing industries, and training workers.[77] Alabama's economic development strategy provides a rich example of multi-faceted supports. Since 1971, the Alabama Industrial Development Training (AIDT) program has prepared workers for manufacturing in auto, machinery, and aerospace jobs. AIDT assumes all the costs of recruitment, assessment, and training for potential workers. By 2012, the program trained over 45,000 workers.[78] It has attracted companies including Hyundai, Honda, Boeing, and truck manufacturer Navistar. Companies that require large cohorts of high-tech workers, including GE and Caterpillar, are considering expansions to the state. Workforce development programs trained people for the jobs that employers needed to fill. State-funded workforce training coupled with other incentives like tax credits have been employed to attract manufacturers.

Manufacturing in a Globalized World

Political and technological changes in the past 20 years have transformed manufacturing. Geographic barriers have been dissolved by telecommunications, advanced shipping and logistics, and the ease of international transportation. Manufacturers are now connected to workers and consumers all over the world due to trade agreements and political shifts which

[75] Emily Clark & Mark Wilson, "Electronics," Encyclopedia of Chicago, 2005.

[76] Glaeser, 2007, p. 6.

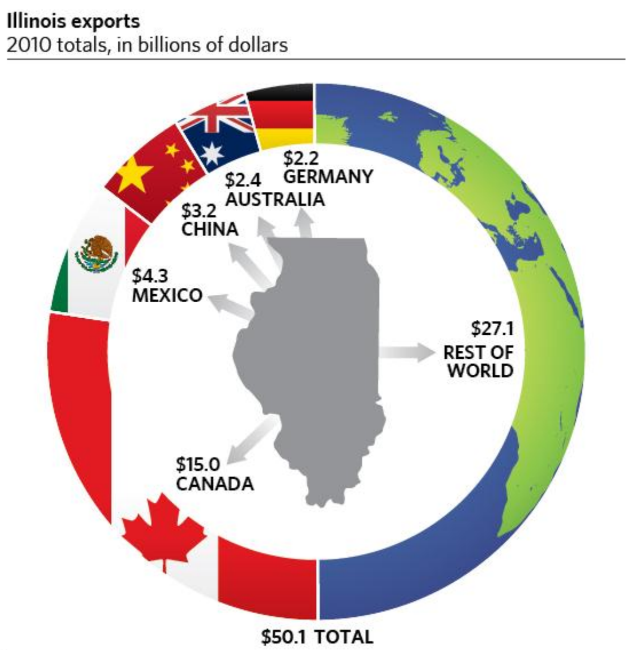
[77] Anthony Carnevale and Nicole Smith, "Breaking Out of the Low Skill Trap in the Southern Economy," Georgetown University, 2012.

[78] Dylan Scott, "Southern States Have Become Leaders in Training," *Governing*, July 2012.

have opened formerly isolated countries to global commerce. At the same time, technological advances in computers and robotics have changed the nature of production on the factory floor.

Over the past two decades, American manufacturers have been able to make and sell their products in more countries than ever before. Enacted in 1994, the North American Free Trade Agreement (NAFTA), a tri-lateral agreement between Canada, Mexico, and the United States, eased tariffs and quotas and reduced other forms of trade-distorting domestic support of industries like agriculture and manufacturing. This agreement has been particularly important for Illinois manufacturers, who have experienced a marked increase in exports year over year. Since 2004, Illinois' exports to Canada and Mexico have increased 134 percent, the largest increase of any other trade partner.[79] Metropolitan Chicago has seen an increase in NAFTA-related freight; the Toronto-Windsor-Detroit-Chicago corridor has one of the highest volumes of transborder truck traffic in the United States.[80]

Figure 22. Leading Trade Partners



Source: Office of the United States Trade Representative, Executive Office of the President, http://www.ustr.gov/about-us/benefits-trade/state-specific-benefits.

China's entry in the World Trade Organization (WTO) in 2001 was another important development for the region's manufacturing cluster. At that point, China was already the world's seventh largest trader. By agreeing to reduce tariffs and other rules and regulations negotiated with the WTO on behalf of its over 150 member-nations,[81] China's economy became wide-open to trade and investment, and it also diminished the possibility of unilateral sanctions from major economies like the U.S. or Europe.[82] In the last decade, China became the default option for companies wishing to compete with low cost nations. Manufacturers were attracted to Special Economic Zones (SEZs), described in the call out box on the following page, because of favorable trade policies, a highly stable currency, lower wages, and government backed capital expenditures.

[79] Merrion, Paul, "Illinois Sets Trade Records with NAFTA Partners," Crain's Chicago Business, May 29, 2012.

[80] Jean-Paul Rodriguez, Brian Slack, and Stephen Blank, "Transport Corridors in North America," The Geography of Transport Systems, Hofstra University, 2012.[81] "Members and Observers," World Trade Organization website, www.wto.org.

[81] "Members and Observers," World Trade Organization website, www.wto.org.

[82] Saich, Tony, "China as a Member of the WTO: Some Political and Social Questions," Harvard University Kennedy School of Government, January 2002.

Planning and infrastructure investments have transformed the landscape of China. In 1988, China had just over 90 miles of expressways, and by 2011, it had nearly 53,000 miles.[83] After a decade of double-digit growth, China now has a large and growing middle class with the purchasing power to consume more. As a result, production has shifted to meet China's domestic demand, and in some cases manufacturers in China have begun producing for that Chinese market in addition to exporting.[84]

China's Special Economic Zones and Industrial Clusters

China's SEZs have attracted thousands of companies, in some cases entire supply chains.[85] China constructed factories, built thousands of miles of roads and rail, reduced or eliminated tariffs, and provided business support services to entice manufacturers or investors.[86] SEZs often included a full complement of industries -- suppliers of every sort were co-located near the OEMs. SEZs have contributed to unprecedented economic growth. From 2000 to 2011, China's exports leapt fivefold to $1.6 trillion.[87] In 2011, Americans imported $99 billion in electrical machinery, $95 billion in power generation equipment, $23 billion in toys, games, and sports equipment, and $21 billion in furniture.[88] Since their creation in the 1980s, SEZs have registered approximately 50,000 invention patents in total, more than 70 percent of which were registered by domestic firms.[89]

Today, China and other Southeast Asian countries are no longer perceived as the inevitable destination for manufacturing. Production there requires significant lag time between each stage of production, which delays a company's ability to take a new idea to consumers. This also requires companies to maintain higher inventories of products in order to respond to fluctuating demand quickly. The supply chain disruptions that occurred as a result of natural disasters in Japan and Thailand also revealed vulnerabilities in long supply chains.[90] Moving manufacturing closer to the consumer eliminates the need to keep large inventories throughout the production process.

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83 Michael Scharenbroich, Garrett Schreiner, Shengyin Xu, "'We're Falling Behind' the Chinese National Highway System," Case Study 4, University of Minnesota, October 2008.

84 Diana Farrell, Ulrich Gersch & Elizabeth Stephenson, "The Value of China's Middle Class," McKinsey Quarterly, June 2006.

85 The Economist, "The Boomerang Effect," April 21, 2012.

86 Between 1997 and 2008, U.S. manufacturing output increased by one-third, to $1.65 trillion, because of strong productivity growth.

87 "U.S.-China Trade Statistics and China's World Trade Statistics," The U.S.-China Business Council.

88 Ibid.

89 Douglas Zhihua Zeng, "China's Special Economic Zones and Industrial Clusters," Let's Talk Development Blog, World Bank, April 27, 2011.

90 Binman Mukherji, "Asia Pacific: Most Vulnerable to Catastrophe, "Wall Street Journal: Japan Realtime, May 11, 2012.

Reshoring: Saving Costs By Moving Home

St. Charles-based Bison Gear produces gear motors for a wide variety of products, from solar panels to ice machines, including many proprietary, custom-designed motors as well. To do so, the factory needs engineers working closely with workers on the factory floor, and a skilled team of machine operators who can change parts over in a machine to switch to the next small run of products. Chinese and Southeast Asian factories are unmatched in producing massive volumes of a single product. However, defects, long delays in shipping, and the advantages of a high-skilled workforce made it easy for Bison Gear to move production back to Kane County. "We can produce them better, faster and cheaper," according to Bison Chairman Ronald Bullock.[91]

Moreover, the advantage of low labor costs has faded with the Chinese government setting wage increases in addition to the 15 to 20 percent they have grown per year in the last decade.[92] Indeed, labor is just one factor in the cost structure of manufacturing, and as factories become more automated, it has become less advantageous to produce so far from consumers.[93] In industries where a factory needs to produce a very limited variety at a high volume, it may still make sense to produce in China. However, for manufacturers in the Chicago region like auto parts and machinery, labor is a small portion of the total cost of production and because production volumes for these goods are modest, it makes sense to move production back to the region. For example, Kane County's Bison Gear and Engineering Company, discussed above, is a prime example of the type of manufacturing in which the region's competitive advantage remains strong and will serve to attract jobs.

Any resurgence of the region's manufacturing will not necessarily be accompanied by a large increase in the size of the labor force. The manufacturing workforce in metropolitan Chicago has shrunk precipitously since 1998,[94] but economists only attribute a quarter of those job losses to changes in imports.[95] Technology has eliminated many low-skilled jobs while increasing productivity in the workplace, and more advanced technology workers are expected to do in one job what took multiple people in the past.[96] Figure 23 shows that while productivity has increased in the past 60 years, employment has fallen since the 1980s. The workforce of more automated factories need much higher skills -- workers must be able to use blueprints to program computer-numerically controlled production machines, preempt breakdowns, assess quality, and maintain the complex equipment.[97]

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[91] Alejandra Cancino and Cheryl V. Jackson, "More Manufacturing Work Returns to U.S. Shores," Chicago Tribune, March 27, 2012.

[92] "Made in America, Again," Boston Consulting Group, 2011, pg. 3.

[93] "Made in America, Again," Boston Consulting Group, 2011, pg. 3.

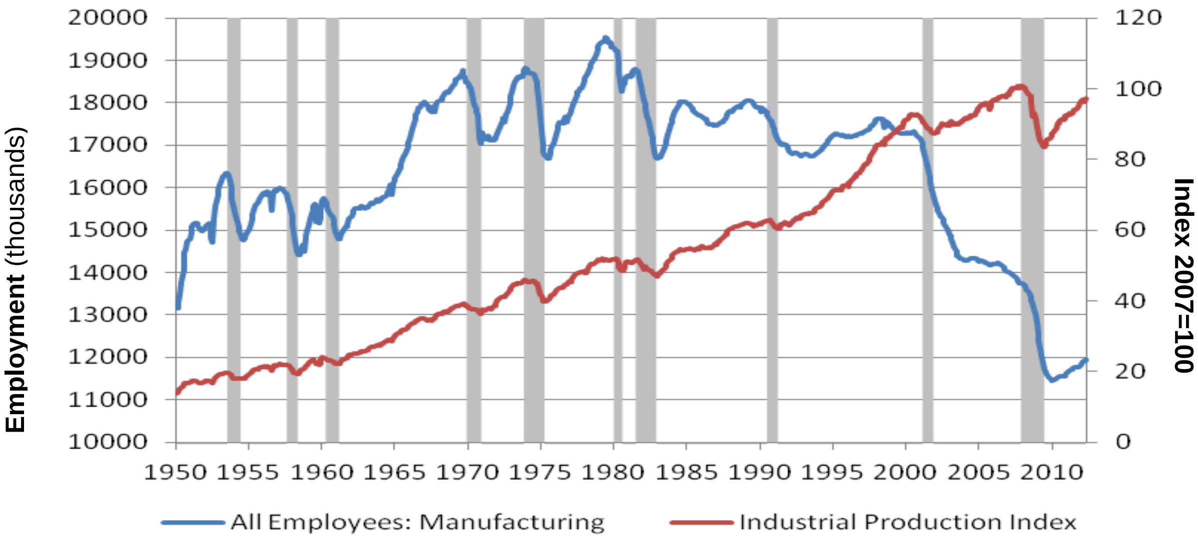
[94] William Testa, "Manufacturing: Been Down So Long, It Looks Like Up?" Blog: Bill Testa on the Midwest Economy, July 13, 2012.

[95] David Autor, David Dorn, & Gordon Hanson, "The China Syndrome: Local Labor Market Effects of Import Competition in the United States," National Bureau of Economic Research, Working Paper 18054, May 2012.

[96] John Markoff, "Skilled Work, Without the Worker," New York Times, August 18, 2012.

[97] Interview with Ray Prendergrast, Director of Manufacturing and Logistics, Richard J Daley College, November 14, 2012.

Figure 23. Manufacturing Employment vs. Industrial Production Index



Source: Federal Reserve Bank of Chicago with data from the Bureau of Labor Statistics/Haver Analytics.

Note: The Industrial Production Index, measures the U.S. output (both measured in physical units and inferred from inputs and production processes) of industries including manufacturing, the raw materials extracted to product products through mining, and the energy used for production through electric and utility companies in the United States.[98]

Overall, this shift toward higher productivity with a smaller manufacturing labor force presents some serious challenges for expanding the labor force. The increased productivity and technology saturation of manufacturing will require a more specialized workforce but the real test is whether American manufacturers have retained their competitive advantage in more advanced stages of production, where workers have complex problem solving abilities on the factory floor and the ability to do precision work.[99]

Manufacturing wages in the U.S. have become increasingly competitive in recent years.[100] Figure 24 shows that while American wages used to be among the highest in the world until the 1980s, they are now close to or lower to similarly skilled manufacturing economies. The index also indicates that overall wages in foreign economies have steadily risen for years, signaling that wages in developing countries have increased significantly.

Some companies in the region have reshored all or a portion of their manufacturing, indicating that metropolitan Chicago still has significant opportunities for production. Will County's Peerless AV, discussed in the call-out box on the following page, recently moved all of its

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[98] "Industrial Production and Capacity Utilization Explanatory Notes," Board of Governors of the Federal Reserve System.

[99] Branson, 1980.

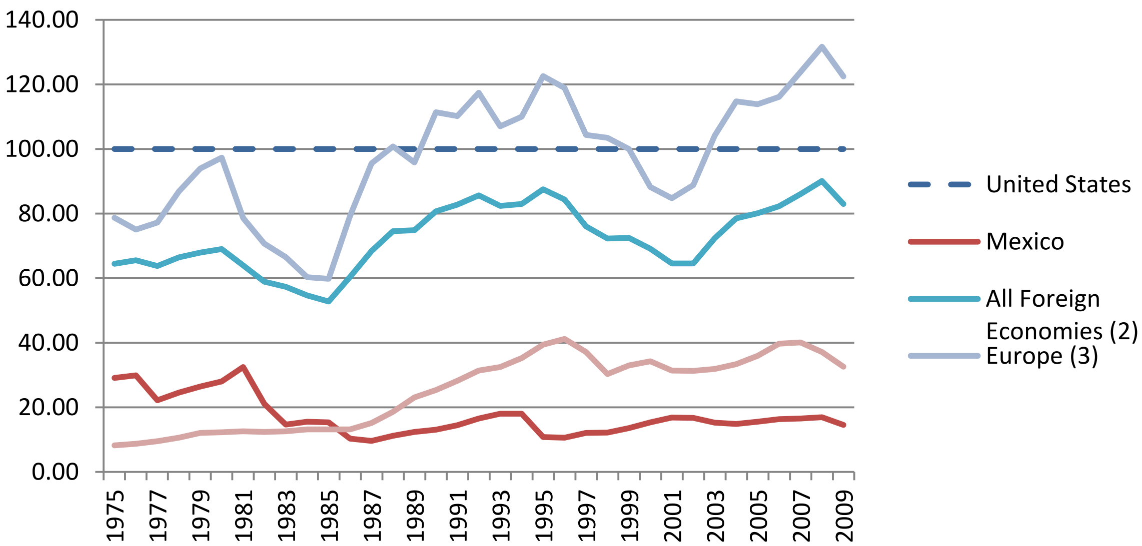
[100] Bureau of Labor Statistics, March 2011.

production back to Aurora to protect its proprietary designs and capitalize on technological advances in factories. After decades of loss in manufacturing, the region may have arrived at a moment to regrow the cluster.

Reshoring: Saving Time and Protecting Intellectual Property

Manufacturers, especially those producing unique technologies or goods, require strong intellectual property-rights protections, a high-functioning legal system, trusted financial markets and solid political institutions with the ability to enforce regulations. According to the Government Accountability Office, the theft of U.S. intellectual property costs American businesses over $250 billion dollars annually.[101] Many manufacturers have learned that manufacturing in China and southeast Asia presents numerous challenges related to intellectual property. Peerless AV, an Aurora-based manufacturer of specialized hanging television stands, moved its production to China in 2002. Peerless went to China to be close to well-priced suppliers. Eight years after the move, flat-screen televisions had boomed and Peerless began to find unauthorized copies of its products all over the world.[102] After re-evaluating the hidden costs of producing in China -- lax intellectual property enforcement and needing 30-days of inventory at each stage product development, Peerless moved back to the region. The company has found that the move has allowed them to be more nimble; they can turn prototypes around to customers in a matter of weeks, not months. Peerless uses robots to do "hot and dirty' jobs like pouring molten aluminum and laser-cutting steel. Although Peerless hired an additional 100 people in Aurora, the company employs 300 fewer workers than it did five years ago.

Figure 24: Index of Hourly Compensation Costs in Manufacturing, in U.S. Dollars



Source: U.S. Bureau of Labor Statistics, March 2011.

Notes: International wages are weighted by the Bureau of Labor Statistics. The measure uses U.S. dollars and value of traded manufactured goods. For a complete description of trade-weighted measures and economic groups, see page 3 the technical notes at www.bls.gov/ilc/ichcctn.pdf. All European Economies exclude Czech Republic, Hungary, and Poland between 1975-96. Those countries in addition to Brazil and the Philippines are excluded in the data for All Foreign Economies during the same time period.

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101 Government Accountability Office, "Intellectual Property," Report to Congressional Committees, April 2010.

102 Alejandra Cancino and Cheryl V. Jackson, "More Manufacturing Work Returns to U.S. Shores," Chicago Tribune, March 27, 2012.

Preparing Metropolitan Chicago for the Future of Manufacturing

The Chicago region could be poised to see a recovery and expansion in its manufacturing cluster. Manufacturers have learned that production in developing countries introduces some imprudent risks for a market that is increasingly demanding more customization and faster turnarounds between design and production. To grow and innovate, metropolitan Chicago must work to address many challenges. Manufacturers must be able to move materials and products in and out of the region without interruptions from congestion on the highways or railways. The region must expand upon its ability to innovate and seize on emerging technological opportunities. The region's workers must be able to learn the skills to make the highest-quality, cutting-edge products. The report now turns to challenges and opportunities in the areas of infrastructure, innovation, and workforce.

Chapter 3: Regional Challenges and Opportunities in the Manufacturing Cluster: Innovation, Workforce, and Infrastructure

After decades of global sourcing, many manufacturers are realizing that the cost advantages of producing overseas for some types of manufacturing may have all but disappeared. Notably, greater customization and faster turnarounds between design and production put pressure on far-flung supply chains already vulnerable to both natural and man-made disruptions. And rising wages abroad -- especially in China -- coupled with decreasing energy costs at home have led more firms to reinvest and expand operations domestically.

To capitalize on this momentum and thrive in a new era of advanced manufacturing, the Chicago region needs to draw on the same competitive advantages that fueled growth a century ago -- economic innovation, infrastructure assets, and a deep pool of skilled workers. The remainder of this report delves into regional challenges and opportunities for each of the three themes of innovation, workforce, and infrastructure.

The innovation section calls attention to the region's recent underperformance in manufacturing R&D, then describes ways to reestablish the region as a leading research center through commercialization, new technologies, and broader R&D support. With innovation and technological change, manufacturing's workforce has shifted as well. The workforce section first describes how recruitment and perception challenges engender a skills gap in the cluster, then the section showcases opportunities to provide both current and future regional workers with the skills they need to respond to a changing field. Finally, the infrastructure section shows how advanced manufacturers increasingly rely on broad infrastructure support, including transportation but also land availability, broadband, capital, and energy, to stay competitive in the global economy.

While international developments will continue to influence manufacturing from afar, each theme of innovation, workforce, and infrastructure represents areas where the region can take proactive steps. As such, each section concludes with a series of broad next steps to support manufacturing in the Chicago region.

Innovation

Innovation is the process of conceiving and developing new products, processes, technologies, and business models that result in goods and services that are faster, cheaper, or otherwise improved. While innovation is important for almost every segment of the economy, it is vital for manufacturing. Past innovations have transformed the cluster -- spawning entire new industries like aerospace or biotech -- and enabled existing industries to thrive through improvements such as just-in-time production and global supply chain management. In an era of worldwide sourcing and globalization, innovation will continue to be the source of future competitiveness for advanced manufacturing regions like Chicago.

> Eighty-seven percent of private R&D in the state comes from manufacturing firms, cementing the link between the cluster and innovation.

Manufacturing accounts for a disproportionate component of the nation's innovative activity: while it makes up only around 11 percent of GDP, 90 percent of all of the nation's patents relate to manufacturing.[103] In Illinois the link between manufacturing and innovation is even more pronounced. Nationwide 68 percent of all private R&D spending comes from manufacturing firms; in Illinois this number rises to 87 percent.[104]

Regional industry clusters spur innovative activity by promoting simultaneous research, design, manufacturing, and supply chain capabilities; these linkages stimulate product improvement and efficiency gains. Additionally, clusters support innovation through enhanced learning curves from economies of scale, joint problem solving initiatives and concentration of subject experts, shared resources to overcome the high costs of product development, and targeted support networks that build on regional strengths. New advancements and complexities in manufacturing will likely make the cluster's role in spurring innovation even more pronounced. [105] As such, a vibrant cluster is an essential component of advanced manufacturing.

The Chicago region must maintain its status as a leading global manufacturing center by promoting innovation to achieve sustained job creation and enhanced economic competitiveness. CMAP's Advanced Manufacturing Scorecard shows how advanced manufacturing relies on product, process, and people innovations to fuel growth and transition into 21st Century manufacturing. This chapter explores the regional manufacturing cluster's challenges and opportunities in product and process innovation (the people indicator is analyzed in the workforce chapter), beginning with an exploration of emerging manufacturing technologies that affect different scorecard industries.

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[103] Information Technology and Innovation Foundation, "The Case for a National Manufacturing Strategy," April 2011, p.13; White House, "A Framework for Revitalizing American Manufacturing," 2009.

[104] National Science Foundation, for year 2007.

[105] Deloitte Consulting LLP, "Reexamining advanced manufacturing in a networked world: Prospects for a resurgence in New England," for the New England Council, December 2009, p. 3.

Emerging Manufacturing Technologies

Metropolitan Chicago's continued shift to more advanced techniques, sophisticated products, and higher-value output in manufacturing draws from a series of evolving technologies. Some of these technologies -- such as robotics or visualization techniques -- have existed for years but recent improvements provide opportunities for industry growth. Other technologies, like nanotech or bio-manufacturing, represent novel developments with the potential to change existing industries and generate entirely new ones. Regional clusters that build expertise and capabilities in emerging manufacturing technologies can capitalize on innovation to out-compete fellow manufacturing centers in the 21st Century advanced manufacturing economy.

Though some nascent technologies never will fully develop into commercial applications and others will emerge unforeseen, those that currently seem to have the most momentum and influence on advanced manufacturing include **advanced materials** and **advanced processes**. This section explores these promising technologies, paying close attention to what regional industries stand most poised to benefit from specific material and process improvements.

Advanced Materials

The tradeoff between weight and strength has often limited the design of many manufactured goods. For example, an automobile's frame must be strong enough to withstand a crash yet this added weight decreases the fuel efficiency of the vehicle. Advances in material science have enabled the development of next-generation materials not just in metals but across all manufacturing so that new goods can be both strong and light. In addition to weight and strength, advanced materials are more flexible, durable, better electrical conductors, can withstand extreme temperatures and chemical exposure, and could be engineered to provide properties that may not even exist in nature. New materials with major manufacturing applications for the regional cluster include *nanotechnology*, *carbon fibers and composites*, and *bio-manufacturing*.

Nanotechnology

Of all advanced materials, nanotechnology may have the broadest applications. This technology works with materials at the nanoscale (nano means a billionth of a meter). At this scale, materials have unique properties that prove beneficial to manufacturers. For example, new drugs can carry information at the nanoscale to target particular cells in the body. Other examples include glass infused at the micro level with a titanium dioxide film that is self-cleaning, thus removing the need for window washers.[106] After years of R&D, nanotechnology seems poised to be commercialized across a variety of industries. In 2005, there were approximately 50 nanotechnology-enabled manufactured products in the nation. Five years later there were over 1,300.[107] According to the Science and Technology Policy Institute, nanotech has "large scale commercial potential across virtually all major economic sectors"

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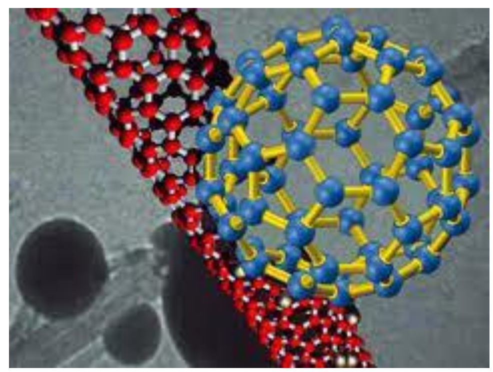
[106] The Economist, "Materials: Forging Ahead," Special Report on Manufacturing and Innovation, April 21, 2012

[107] Illinois Science and Technology Coalition, "Nanotechnology Facts & Figures," 2012.

including heavy manufacturing, energy production and distribution, medical equipment, transportation machinery, and a host of other uses.[108] Of all applications, nanotechnology will probably be implemented first in automobiles, chemicals, electronics, and health sciences. The Illinois Science and Technology Coalition notes that the global market for nanotechnology in these four manufacturing industries will reach $2.41 trillion by 2015.[109]

Region's Nanotech Hub

Of all emerging manufacturing technologies, the region may be best positioned to realize advances in nanotechnology. **A recent study that looked at nanotechnology capabilities in research and education ranked Illinois fourth in the entire world.** Anchoring this strong showing was Northwestern University, whose research and commercialization activities in nanotech ranked second domestically in the same study. Further regional competencies in nanotechnology development include the Center for Nanoscale Materials at Argonne National Laboratory and the University of Chicago's The James Franck Institute, as well as specializations downstate at the University of Illinois. Translating this research expertise into commercial innovations could help distinguish the region's manufacturing cluster in the 21st Century.



Source: Illinois Science and Technology Coalition, "Nanotechnology Facts & Figures." Image from rsc.org.

Bio-Manufacturing

While nanotechnology will allow researchers to create materials with properties not seen in nature, bio-manufacturing seeks to replicate some of nature's most useful systems, such as self-assembly or self-healing materials. Bio-manufacturing uses a biological substance as its main product, and is driven by advances in genetic engineering, metabolic engineering, synthetic biology, and the broader life sciences. For example, researchers at the Massachusetts Institute of Technology (MIT) have created viruses that are harmless to humans but can interact together and bind to produce elements such as cathode and anode for eventual use in a battery. These bio-inspired materials enable highly customizable materials (the researchers created a billion viruses and selected those with the best attributes), produce almost no waste, and are very environmentally friendly.[110]

Bio-manufacturing is still in its early stage. Though some firms currently employ bio-inspired manufacturing techniques, key technologies will need to be scaled-up to enable widespread adoption. On a shorter time frame, bio-manufacturing seems most applicable to the pharmaceutical industry, as well as in fuels and foods. On a longer horizon, developing new

[108] Science and Technology Policy Institute, "White Papers on Advanced Manufacturing Questions." Prepared for the Advanced Manufacturing Workshop of the President's Council of Advisors on Science and Technology, April 2010, 1-9.

[109] Illinois Science and Technology Coalition, "2012 Illinois nanotechnology report: A road map for economic development."

[110] The Economist, "Materials: Forging Ahead," Special Report on Manufacturing and Innovation, April 21, 2012

materials that can self-assemble, regenerate, or grow will have applications in almost every manufacturing industry.

Carbon Fibers and Other Composites

Carbon fiber is a material made of carbon atoms bonded together in crystals and aligned to form a fiber. Carbon fiber can be as strong as steel but only half the weight. First utilized in aerospace, carbon fiber composites quickly have spread into more industries, with the most applications in machinery and fabricated metals.[111] Firms already have found uses for composites, offering products ranging from carbon fiber iPhone casings to stronger motorcycle helmets. The carbon fiber manufacturer Zoltek predicts a $2 billion market for commercial carbon fibers by 2015, and notes that most of this growth will come from commercial applications outside of aerospace.[112]

Advanced Processes

Process improvements will give regional manufacturing firms the tools to respond to ever changing customer demand, add efficiencies in the production line, and improve design, research, and supply chain capabilities. New processes that will affect the future of manufacturing include *additive manufacturing*, new *robotics and automation*, and the *digitization* of the field.

Additive Manufacturing

Much of manufacturing in the past has centered on transforming stock materials into refined goods. This involves bending, drilling, cutting, and shaving off excess, producing large amounts of scrap material in the process. For example, aerospace often forms parts out of a solid billet of high-grade (and very expensive) titanium. Up to 90 percent of the material can be cut away in the process; this scrap is of little further use.[113]

In contrast to subtractive manufacturing, the additive manufacturing process adds materials layer by layer, using just the amount of materials needed and thus producing no scrap. The chief instrument of additive manufacturing is a 3D printer that functions much like an office printer: while an office printer

Regional Firms Develop Cutting Edge Manufacturing Technologies

Next-generation technologies already shape regional manufacturing activities. Microlution, a Chicago-based machine tool manufacturer, is developing a bio-manufacturing material that mimics the texture of shark skin to block bacterial growth in hospital machinery. Applied Material Systems Engineering in Schaumburg combines composite materials with nanotechnology that has applications for NASA space exploration. And Biomedical Acoustics Research Company in Evanston is researching an early detection device that measures changes in low-frequency chest wall vibrations, allowing early intervention to prevent heart failure. These are just three examples out of many regional firms developing and implementing technologies that will shape future manufacturing activities.

Source: Small Business Innovation Research, 2011.

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[111] Ibid

[112] "Commercial Carbon Fiber," Zoltek, http://zoltek.com/carbonfiber/the-future-of-carbon-fiber/

[113] The Economist, "Additive Manufacturing: Solid Print," Special Report on Manufacturing and Innovation, April 21, 2012

moves back and forth inserting ink over a page, a 3D printer deposits materials (such as mineral powders or sprayed plastics) layer by layer to build a product. In addition to saving on material costs, additive manufacturing can produce goods with improved properties.

In traditional manufacturing the cost of the first unit of production is enormously expensive. For example, the cost to produce one car includes the millions spent on R&D and product testing as well as developing a supply chain and setting up a manufacturing plant. To overcome the high costs of the first unit of production, manufacturers mass produce to spread these initial costs out over hundreds of thousands of vehicles. In additive manufacturing the cost of the first unit of production is much less, coming mainly from the time to program the 3D additive printer, which will allow much more customization in manufacturing orders.

When 3D printers first began to be sold in the late 1990s they were the size of industrial refrigerators and cost hundreds of thousands of dollars. Today such printers can cost as little as $1,500 and are small enough to fit on a desk. Consumer research experts predict that in the next few years additive manufacturing will take off, spreading to small manufacturers and even home hobbyists tinkering in their garage.[114] The applications seem endless; 3D printers are already used to make a wide variety of items from auto parts, to shoes and guitars.[115] The proliferation of additive manufacturing will affect almost every regional manufacturing industry, though it seems most poised for those dealing with low-scale, highly-customized production such as personalized medicine or machine shops and other fabrication activities.[116]

Robotics and Automation

While automation in manufacturing is certainly not new, recent process advancements are transforming manufacturing lines. According to two MIT economists, "the pace and scale of this encroachment into human skills is relatively recent and has profound economic implications."[117] These recent improvements in robotics often center on visualization and telematics. Improved camera technology better syncs robots on the production line and can be used as a form of quality control. Telematics, or sensors that feed real-time information, allow a robot to feel when something goes wrong; future iterations of robots will use telematics to auto-correct and adjust. Manufacturers will continue to adopt automation where feasible, but as robotics continues to be expensive, the industries that seem most likely to be affected will be mass production industries such as automotive or computers.

Digitization and Visualization

Finally, information technology (IT) plays as important a role in manufacturing as it does in any of the service sector industries. Improving information technologies by digitizing data and increasing processing power and software efficiencies offers numerous benefits for

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[114] Cecilia King, "3-D printers could bring manufacturing to your home office," Washington Post, January 7, 2013.

[115] Ibid.

[116] The Economist, "Additive Manufacturing: Solid Print," Special Report on Manufacturing and Innovation, April 21, 2012

[117] Erik Brynjolfsson and Andrew McAfee, quoted in John Markoff, "Skilled Work, Without the Worker: New Wave of Deft Robots is Changing Global Industry," New York Times, August 19, 2012.

manufacturers. Digitization will allow firms to more easily share information, make training easier as workers can train on simulators that mirror actual production machines, and improve conceptualization that allows prototypes to be developed quickly and cheaply. Visualization will also help sync production design and assembly. Of all technologies shaping manufacturing in the future, improved IT likely has the broadest industry applications across the region's diverse manufacturing output.

Innovation Challenges and Opportunities

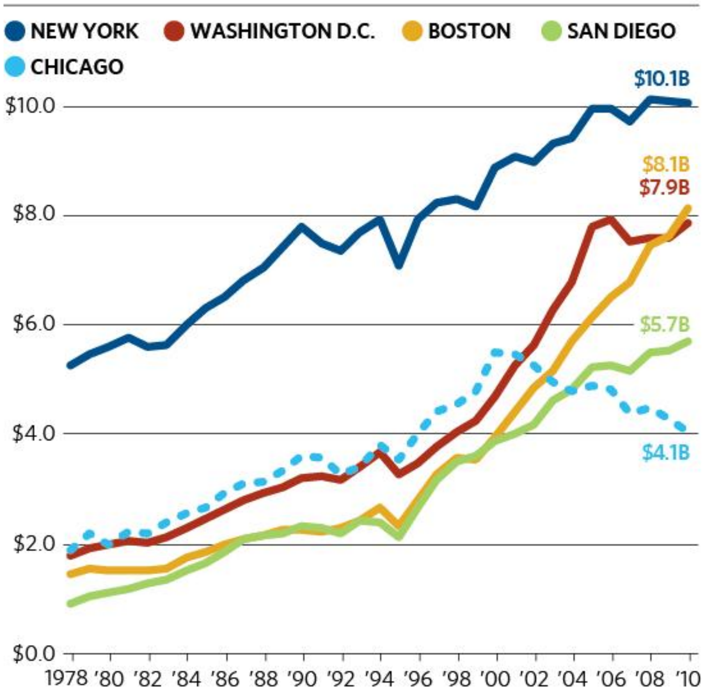
How the Chicago region adopts and utilizes emerging material and process technologies to compete in global advanced manufacturing will depend on capabilities in its innovation infrastructure. As the nation's second largest manufacturing cluster, metropolitan Chicago has developed and benefited from a regional system of manufacturing innovation assets such as universities, national labs, and private R&D. Despite this existing innovation base, recently the region has fallen behind many peer innovative regions and it now underperforms in many manufacturing innovation indicators.

Chapter 1 of this report calls attention to the most noticeable indicator suggesting the region's innovation base is deteriorating -- declining employment in firms primarily engaged in R&D, a stark reversal from the region's historical trend. As documented earlier, between 1970 and 2000 the Chicago tri-state region tripled its employment in scientific R&D,[118] making it second only to the New York region. Beginning in the new century however, the Chicago region saw this strength erode at the same time that peer metro areas grew their R&D employment. In addition to employment losses, the contribution of these R&D firms to Chicago's regional economy also fell this last decade, as portrayed in the graph on the following page. During this decade-long trend the region has been losing ground against smaller innovative regions like San Diego, Boston, Silicon Valley, and San Francisco. As these regions enhance the R&D intensities of their manufacturing clusters and the Chicago region lags behind, it becomes harder for northeastern Illinois to adopt new technologies and compete in global advanced manufacturing.

To reverse this trend and position the region toward the next generation of advanced manufacturing technologies, the region's manufacturing cluster must overcome innovation challenges and better capitalize on existing innovation assets. This section explores the leading challenges and opportunities facing our region, starting first with regional manufacturing R&D and then turning to the commercialization of that research and technology.

[118] Scientific R&D (NAICS 5417) measures firms primarily engaged not only the R&D essential to manufacturing such as engineering or the physical and life sciences, but also that in the social sciences and humanities. Scientific R&D is used for historical comparisons as it is not possible to isolate types of R&D prior to the year 2000. Scientific R&D is still a good measure of manufacturing innovation because social science and humanities R&D is both small and fairly constant through time.

Figure 25. Scientific R&D's Contribution to Gross Regional Product by Metro Area: 1980-2010



Source: February 2012 Illinois Innovation Index. Output is measured in billions of dollars.

Starting in 2000 the Chicago region has lost ground in firms primarily engaged in R&D. For example, scientific R&D output in the Chicago region was 40 percent larger than the Boston region in the year 2000; ten years later Boston's regional output doubled that of the Chicago region. The decline in primary R&D is the primary innovation challenge facing our manufacturing cluster

Innovation Opportunity: Basic R&D Infrastructure

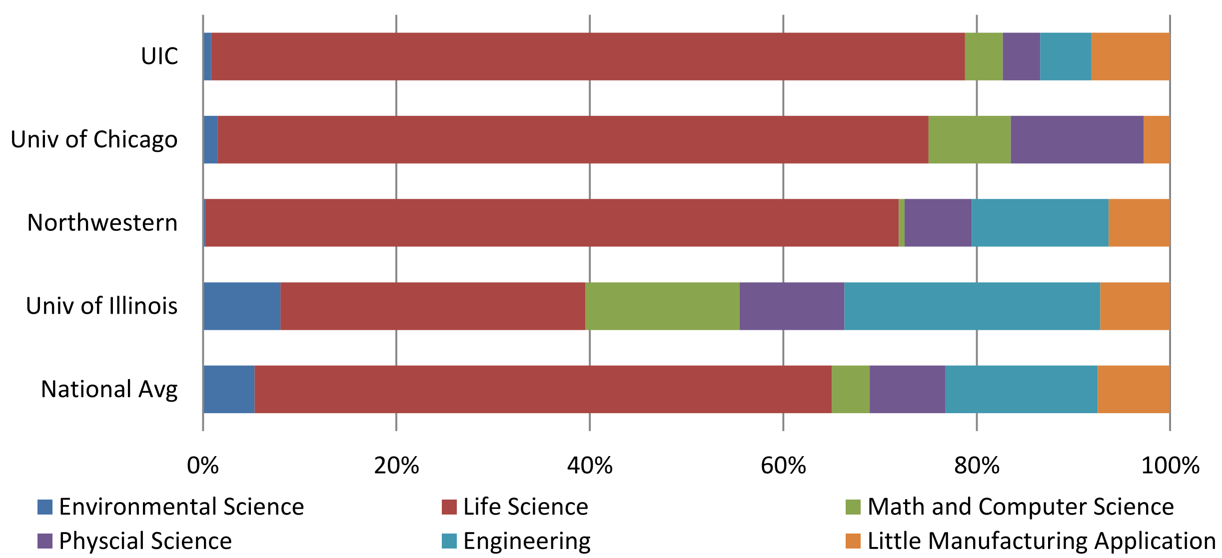
Basic research expands the base of human knowledge by exploring fundamental principles and scientific questions with less regard to future commercial applications. In the long term, these advances serve as the foundation for all new commercial products brought into the market. Since basic research traditionally has had fewer immediate applications, it is funded almost primarily by the public sector through two types of institutions: universities and national labs. While the region has struggled recently from a loss of private firms primarily engaged in R&D, it maintains one of the nation's foremost centers for basic research through its universities and national labs. A key innovation opportunity for the cluster is to build off this existing base.

Regional Universities

Of all basic research, science and engineering has the most potential for manufacturing applications. In 2009, universities in Illinois conducted nearly $2 billion of this science and engineering R&D, the seventh largest outlay of any state. Three of the region's universities (University of Illinois at Chicago [UIC], Northwestern University, and University of Chicago) as well as the University of Illinois Urbana-Champaign were responsible for 85 percent of this R&D. Along with other institutions, these four universities constitute a tremendous asset for the region: all are in the top 60 nationally for R&D expenditures in science and engineering, led by University of Illinois (ranked 27th nationally in expenditures), followed by Northwestern (30th), University of Chicago (48th), and UIC (57th).[119]

Analyzing each institution by specialty calls attention to where the region excels in the basic R&D that has the most potential to be later applied to manufacturing. The life sciences make up nearly three quarters of all R&D expenditures at Northwestern University, University of Chicago, and UIC, far above the national average of 60 percent. As the life sciences are most relevant to pharmaceuticals, medical equipment manufacturing, and the emerging broader field of bio-manufacturing, these regional universities are major assets for the region's health sciences manufacturing cluster. The University of Chicago also maintains a strong math/computer science and physical science focus while Northwestern is well-known for engineering research. Downstate, the University of Illinois conducts less life science work but is above national levels in environmental, math/computer, and the physical sciences, with an even more pronounced concentration in engineering.[120] The following graphic captures each university's distribution in science and engineering R&D.

Figure 26. R&D Expenditure at Regional Universities, 2009



Source: CMAP analysis of National Science Foundation (NSF) data

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[119] National Science Foundation data for FY 2009.

[120] Ibid.

National Labs

In addition to basic research conducted at universities, over $16 billion in R&D expenditures occurred at the national labs in 2009. The Chicago region is home to two of the largest: Argonne National Laboratory and Fermi National Accelerator who together in 2009 conducted over $1 billion in R&D expenditures.[121] Metropolitan Chicago is one of only four domestic regions containing at least two national labs. The presence of these two labs -- both major global centers of research -- serves as a huge advantage for the region by providing advances in basic research that can fuel growth in regional advanced manufacturing industries.

Fermi National Accelerator Laboratory (Fermilab), located outside of Batavia near the Kane/DuPage border, focuses on high-energy particle physics and neutrino experiments. Though this basic research often is far removed from commercial applications, it serves as the foundation of many important advances. For example, basic research in particle physics has led to new superconducting materials with improved power transmission and data sharing while the medical field has applied breakthroughs in basic physics to produce medical diagnosis technologies like MRIs or PET scans. Fermilab also shows how advances in basic research can often have unintended spillover effects with widespread practical applications -- the internet partly grew out of efforts of particle physicists to communicate with distant colleagues. The nation's first web site was at Stanford's Linear Accelerator Center and the second was at Fermilab. Despite these important contributions, recent budget woes have dampened the pace of research at the lab. Fermi's particle accelerator closed in 2011 and budget cuts have forced cutbacks in staff and projects. Most concerning, many cutbacks target long-range projects, perhaps calling into question the long-term research viability of the lab.[122]

Argonne, located in DuPage County, was the first science and engineering national lab in the country and is the largest in the Midwest, staffing 3,500 fulltime employees. Argonne focuses on broad research in the life, physical, and environmental sciences. It maintains over 200 active research projects in a variety of fields. Some research projects with the most applications for regional manufacturing include:

- Energy efficiency and alternative energy
- Nanotechnology
- Energy storage (especially in batteries)
- Material science
- Super computing
- Biological systems

The presence of two premier national labs in the region is a huge innovation asset. First, the two labs attract top international talent to the region both as staff at the labs and also as visiting researchers. Research at the labs also fosters partnerships with other elements of the regional innovation ecosystem, such as universities. For example, cutting-edge research on self-healing

121 Ibid.

122 Paul Merrion, "More Fermilab layoffs loom," Crain's Chicago Business, February 27, 2012.

materials with applications in oil and gas drilling, space exploration, and other environments with extreme exposure and stress was co-authored by researchers at the University of Illinois and Argonne.[123] Additionally, research at the national labs builds regional expertise in a variety of fields -- Argonne is perhaps the world's leading center for batteries and its Center for Nanoscale Materials fits well with the region's emerging nanotech cluster. Finally, most national labs in the nation are relatively isolated geographically, making it more difficult for them to incorporate into clusters of innovation. In contrast, both Argonne and Fermi are situated within a metropolitan area, facilitating the connection to industry looking to commercialize technology.

Innovation Challenge: Applied Private R&D

Unlike basic research which aims foremost to increase understanding of fundamental principles, applied R&D seeks to develop research that soon will have value in the marketplace. While basic R&D usually occurs in universities and national labs, private firms conduct the majority of applied R&D. Sometimes this takes the form of public-private research collaboration, but private firms also conduct internal research not necessarily tied into the public research system. Since applied R&D's goal is to develop into commercial use, the region's decline in primary R&D firms inhibits the cluster's ability to put forward the next generation of advanced product and process. The decline is even more troubling because private research represents an increasing proportion of all R&D spending across the nation, rising from about half of all domestic R&D outlay in the 1980s to 62 percent in 2009.[124]

Extended R&D Tax Credit

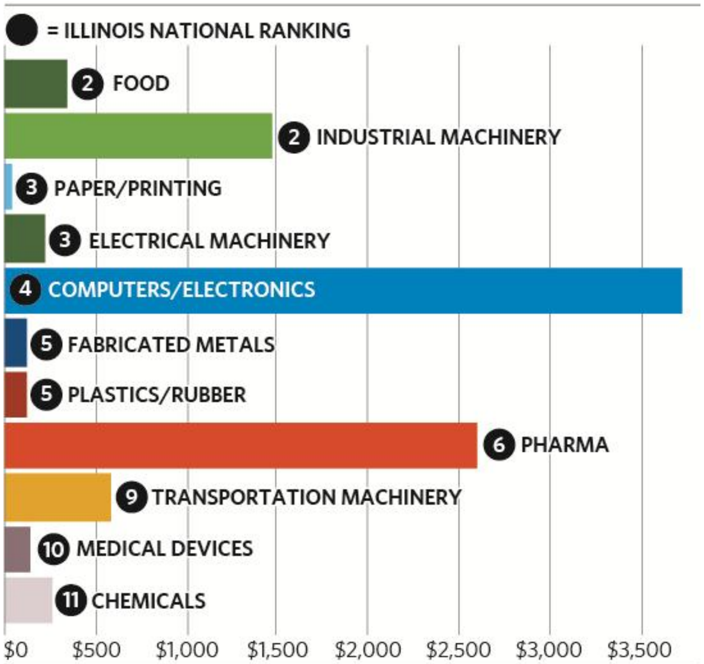
In December 2011, Governor Quinn signed legislation extending the Illinois R&D tax credit for another five years while allowing earned credits to be used even without future extensions. By preserving the state's R&D credit, the bill provides an incentive for private firms in the state to conduct the applied research that is essential for manufacturing innovation and commercialization. The extension also allows the state to continue to compete with other regions and countries that have their own R&D incentives.

Over 87 percent of all private R&D conducted in Illinois comes from firms in manufacturing, much higher than the national rate and affirming manufacturing's importance to the regional innovation economy. As the nation's second largest cluster the region still sustains private research specialties in a number of fields, and overall private firms in the state spent almost $10 billion on manufacturing R&D in 2007 (the most recent year when data are available). The following section describes how Illinois stacks up against the rest of the nation in private manufacturing R&D, showing that even with a regional decline in some applied R&D the region still maintains specializations across a variety of industries.

[123] Paul Rincon, "Time to heal: The Materials that repair themselves," BBC News Science and Environment, October 30, 2012.

[124] Illinois Innovation Index analysis of Moody's Analytics, February 2012 edition.

Figure 27. Private Manufacturing R&D in Illinois, in millions of dollars



Source: CMAP Analysis of NSF data for year 2007.

Private manufacturing R&D in Illinois occurs across most major industries, reflecting the diverse output of the cluster. This graphic measures statewide manufacturing R&D in absolute numbers as well as shows how this expenditure ranks compared to other states (with the rank for Illinois measured by the black circle to the right of each bar).

Overall Illinois is the second largest center of private R&D for food and commercial/industrial machinery. Food as an industry conducts much less R&D compared to machinery, reflected in the chart above. The state ranks third on paper/printing and electrical machinery private research and fifth in fabricated metals and plastics/rubber. All these industries expend relatively less on private R&D both in the state and nationally. Nationwide, computers and electronics accounts for the most R&D of any industry; in 2007, private firms in Illinois expended over $3.5 billion in the industry, the fourth highest level in the nation. Though the data do not de-aggregate to lower industry levels, it is probable that much of the $3.5 billion went to communication and electronics research compared to semiconductors and other computer components.[125]

Pharmaceuticals was the second highest overall private R&D outlay in Illinois with about $2.5 billion in private R&D spending, yet this level was only sixth highest among all states. The state ranked much lower on medical devices and chemicals. Both these industries ranked high on the advanced manufacturing scorecard, suggesting more work needs to be done to build up the region’s ability to bring novel technologies to these market segments.

[125] CMAP analysis of National Science Foundation data.

Innovation Challenge: Applied R&D Gap for Small and Medium Manufacturers

According to analysis by the Brookings–Rockefeller Project on State and Metropolitan Innovation, most small and medium-sized manufacturers conduct no or little R&D since they lack resources and in-house expertise. Additionally, these smaller firms find it harder to adopt university research and in general have much less familiarity and know-how around emerging technologies. Yet as more final equipment manufacturers subcontract all but their core capabilities, many small and medium-sized firms are now expected to not only make but also design more and more of intermediate and final manufactured goods.[126] In the Chicago region the R&D gap for small manufacturers may be more acute, as R&D specific firms have declined the past decade. With this decline smaller firms have fewer options to contract out for R&D.

As with manufacturing in the nation, small-sized manufacturers make up the vast majority of manufacturing firms in both Illinois and the region -- 83.9 percent of all manufacturing firms in metropolitan Chicago employ less than 50 workers, nearly identical to the distribution in the state (83.7 percent). Medium-sized manufacturers make up almost the entirety of the remainder. Thus large firms (above 500 workers is the division most commonly used separating medium from large manufacturing firms) represent less than one percent of all manufacturing firms in both the region and the state.[127]

Illinois Manufacturing Extension Center

The Illinois Manufacturing Extension Center (IMEC) focuses on helping small and medium-sized manufacturers in the state stay competitive. Through technical assistance, IMEC helps firms respond to a more demanding global economy, including programs on innovation and advanced technology adoption. According to the organization's website, since 1996 IMEC has helped over 2,500 small manufacturers in the state realize $1.5 billion in cost savings.

Though less than one percent of all manufacturing firms, large-scale manufacturers conduct and fund 86 percent of all industrial R&D in the state.[128] Conversely, small-sized manufacturers are responsible for just six percent of R&D. The chart on the following page visualizes this R&D gap for small and medium-sized manufacturers. Since small manufacturers play such an integral role in manufacturing supply chains, helping these firms transition to advanced manufacturing could give the region a competitive edge over peer manufacturing clusters and help address the decline in primary R&D.

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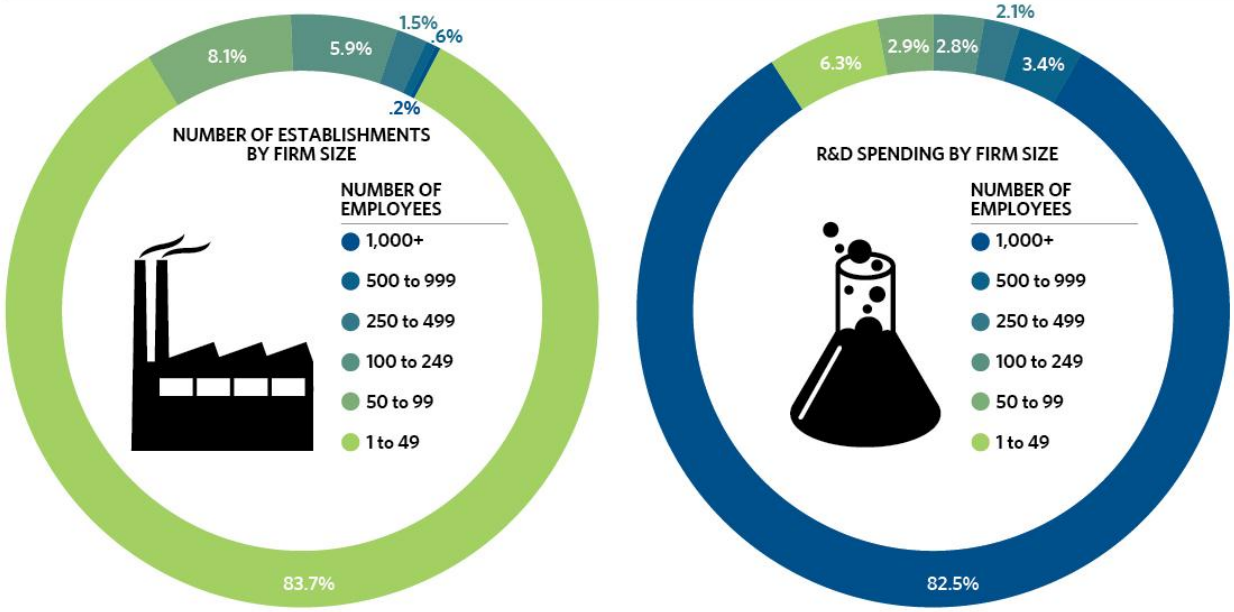
[126] Susan Helper and Howard Wial, "Accelerating Advanced Manufacturing with New Research Centers," Brooking-Rockefeller Project on State and Metropolitan Innovation, February 2011, p.3.

[127] CMAP analysis of U.S. Census County Business Patterns data.

[128] Sufficient data for the Chicago region are lacking, but a similar number could be expected for the region given the similar distribution by employment class size.

Figure 28. Manufacturing R&D Spending by Size of Firm in Illinois



Source: CMAP analysis of NSF data.

Innovation Challenge: Tech Transfer and Commercialization of R&D

R&D is a fundamental component of human discovery. From an economic development perspective however, advances in basic and applied research best support the regional economy when they are translated into products of commercial value. Despite the region's manufacturing-related research at national labs, universities, and private firms, the economic benefits of innovation can be stifled by the challenges of transferring ideas and discoveries into products or models that take hold in the private market. This section measures commercialization efforts from research at regional universities, national labs, and private firms to show how more can be done to support technology transfer into the cluster.

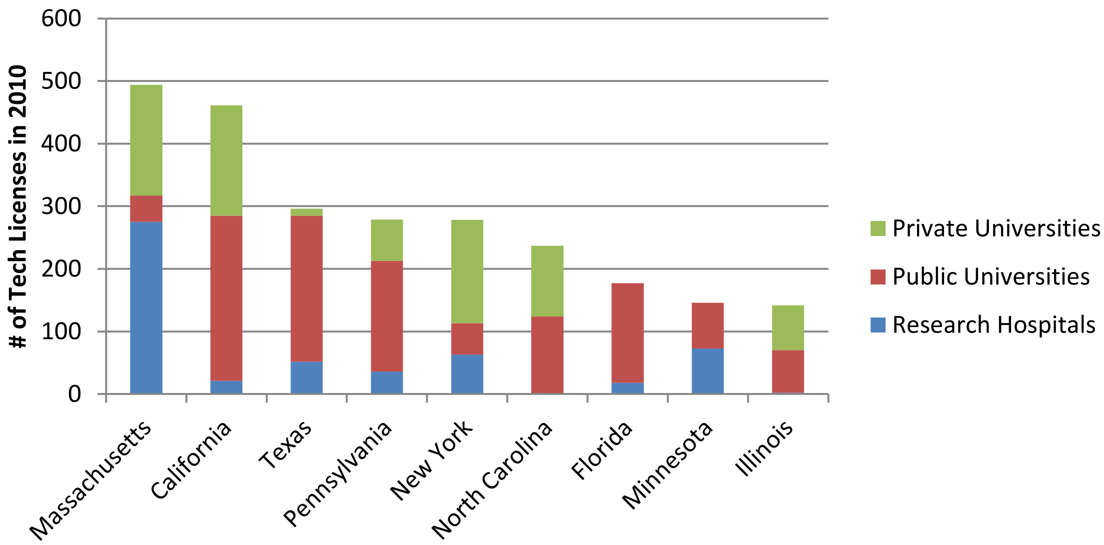
Technology Transfer at Regional Universities

Once university research has progressed past the foundation stage, technology can be transferred to the private market for commercial development. In today's hyper-competitive innovation economy the line between basic, applied, and adopted research is blurring as universities across the globe have become more entrepreneurial in their research aims while private firms seek to quickly transform basic discoveries into commercial products. According to the Illinois Innovation Index, the transfer of research conducted at regional universities into the private market has accelerated. Despite this positive trend, institutions in other states continue to outperform those in Illinois.[129] A leading indicator to gauge a university's success at technology transfer to the market is technology licensing, which measures university licensing of patented technologies to private companies.

[129] Illinois Innovation Index, August 2012 edition.

In 2010, universities in Illinois licensed 142 technologies to private companies, a nine percent increase from 2007 levels. In absolute numbers, this falls far below Massachusetts (494 licenses) and California (461 licenses), the top states for university tech transfer. Compared to states of a more similar size, Illinois performs better, though still behind states such as Pennsylvania (279 licenses, a 51 percent rise in licensing past four years) or Florida (177 licenses, a 33 percent rise the past four years). University licensing data show how academic institutions across the nation are intensifying tech transfer efforts; Illinois universities are making progress but still have to make up ground compared to other states.

Figure 29. 2010 University Tech Licenses by State



Source: Illinois Innovation Index, August 2012.

Not all technology transfer licenses are of equal value in the marketplace, so focusing on total executed licenses only tells a partial story. A look at technology licenses by revenue complements the analysis of total number of licenses -- higher university revenue from individual licenses suggests some R&D output has more practical and revenue generating applications as industry is willing to pay more for the intellectual property. Total revenue flowing to Illinois universities from technology licensing tells a mixed story. The state has the third most licensing revenue from 2002 to 2011, though the lion's share of this revenue comes from a single license, that of the anti-seizure drug Lyrica developed by a professor at Northwestern University. Indeed, almost all of Northwestern's licensing revenue came from Lyrica's $1.36 billion windfall. If Lyrica is removed from the state's total, Illinois drops from third to 16th in total licensing revenue. As Andrew Wang of Crain's Chicago Business argues, Lyrica's success "masks a lackluster record of entrepreneurship at Illinois institutions of higher education."[130] Except for Lyrica, regional universities have struggled turning faculty discoveries

[130] Andrew L. Wang, "Northwestern University leads nation in tech transfer revenue," Crain's Chicago Business, October 29, 2012.

into commercially viable products: the University of Chicago received $82.6 million in licensing revenue from the entire 2002-11 period, and the University of Illinois system just $99.2 million the same period.[131] To put those numbers in context, national leaders in tech transfer such as New York University or Columbia University surpass these decade-long revenue totals in a single year.[132]

Lyrica shows how profitable tech transfer can be. An opportunity exists to build off the success of the region's blockbuster drug through more commercialization of university research. In the period between 2007 and 2011, the largest six universities in Illinois (excluding Northwestern and its Lyrica revenue) collectively doubled their technology licensing revenue compared to the 2002-06 period, suggesting positive momentum moving forward.[133] Continuing this momentum can help regional manufacturing firms better compete in the global advanced manufacturing market as technologies are more broadly commercialized within the region.

Spurring Commercialization: Business Incubators and Tech Parks

Business incubators and technology parks assist the growth of companies seeking to commercialize technology by providing space, resources, and support. Often they serve as a vital link propelling a novel idea into a practical business plan, helping connect investors to research coming out of the university system. A well-known national example is the Research Triangle Park in North Carolina, situated to build off research at Duke, University of North Carolina, and North Carolina State, now the largest tech park in the U.S.

The Chicago region can learn from the success of this model. One promising regional example comes from patented material now used in lithium-ion batteries that was developed at the Illinois Institute of Technology's electrochemical engineering labs. This technology formed the basis of AllCell, which was the first tenant at the University Technology Park at IIT. After a successful incubation period at the technology park, AllCell has expanded operations to a facility in Chicago. In addition to IIT's Technology Park, further regional assets include the Illinois Science + Technology Park in Skokie and the Chicago Technology Park in the Illinois Medical District. Both these centers are especially attuned to the region's nanotech and health sciences concentrations.

Source: Illinois Innovation Index and World Business Chicago.

Technology Transfer at the National Labs

While the broad research of the region's national labs is a major asset, more work can be done in steering projects towards commercial development. Like other institutions conducting basic research, national labs face difficulties with the so-called "valley of death" between publicly funded research and private investment -- many federal grants for basic research in fact preclude commercialization activities while private sources tend not to invest in technologies whose commercial viability is still years away.[134]

[131] Ibid.

[132] Association of University Technology Managers (AUTM), annual surveys.

[133] Wang, 2012.

[134] CMAP interview with World Business Chicago, November 28, 2012.

The financing challenge of commercializing basic research isn't unique to the Chicago region, though the region's national labs could likely improve the tech transfer process. First, scientists looking to spin-out a new technology generally lack startup expertise. Here the labs could offer or make connections to more business resources, replicating the commercialization advantages of places such as North Carolina's Research Triangle. To better attract private investors with commercialization expertise, the labs also could spend some extra effort to catalog all available technologies into a single and easily-accessible resource.

Promising Model: Germany's Fraunhofer Institute Catalyst for Innovation

The Fraunhofer Institute, Germany's equivalent to the U.S. research laboratory system, offers valuable lessons on how to advance promising ideas into the market. The institute benefits from the German tradition of cooperation between private business and public research projects. While the lion's share of funding for national labs in the U.S. comes from the government, at the Fraunhofer Institute an estimated 70 percent of research is generated through public-private research collaboration. Not only does this expand funding, it also increases commercialization by allowing the private sector to be a fundamental partner throughout the entire research process, not just at the end.

Source: Brookings and World Business Chicago.

Further opportunities to increase commercialization may exist by adjusting incentive structures at the regional labs. Often technology transfer at the labs takes the form of licensing patented technology. Though this financing model helps meet short term operating budgets at the labs, generally only larger firms have the resources to buy licenses. Compounding the issue, some larger firms may not even advance the licensed technology into the market, but instead secure the patent to stave off market penetration from startups and other competitors. Augmenting or altering the national lab's current licensing scheme in favor of a shared revenue structure may help improve technology transfer. The shared revenue could be based less on upfront revenue through a license and instead on future proceeds the technology accrues in the marketplace. This would help both prioritize the technology most ready for the marketplace as well as incentivize private companies to move quickly with market adoption. Finally, by basing technology transfer not on upfront licensing costs but on success in the marketplace, shared revenue could encourage smaller firms who lack the ability to buy licenses upfront to still move forward with commercialization.[135]

Finally, though both Argonne and Fermi are both situated within the Chicago region, they may be underutilized resources that could be better integrated with other parts of the innovation economy. Many of the companies working with the labs to commercialize technologies actually come from out of the state or even the country. For example, Argonne's highly successful license of patented battery technology went to the Korean battery giant LG Chem who had the resources and technical knowhow to develop a commercial use for the technology, building batteries for Chevrolet's Volt at a plant in Holland, Michigan.[136] Both labs can certainly work to showcase emerging technologies to local firms but the impetus is also on regional firms to better utilize these world-renowned resources. Enhancing the connection between the region's

135 Ibid.

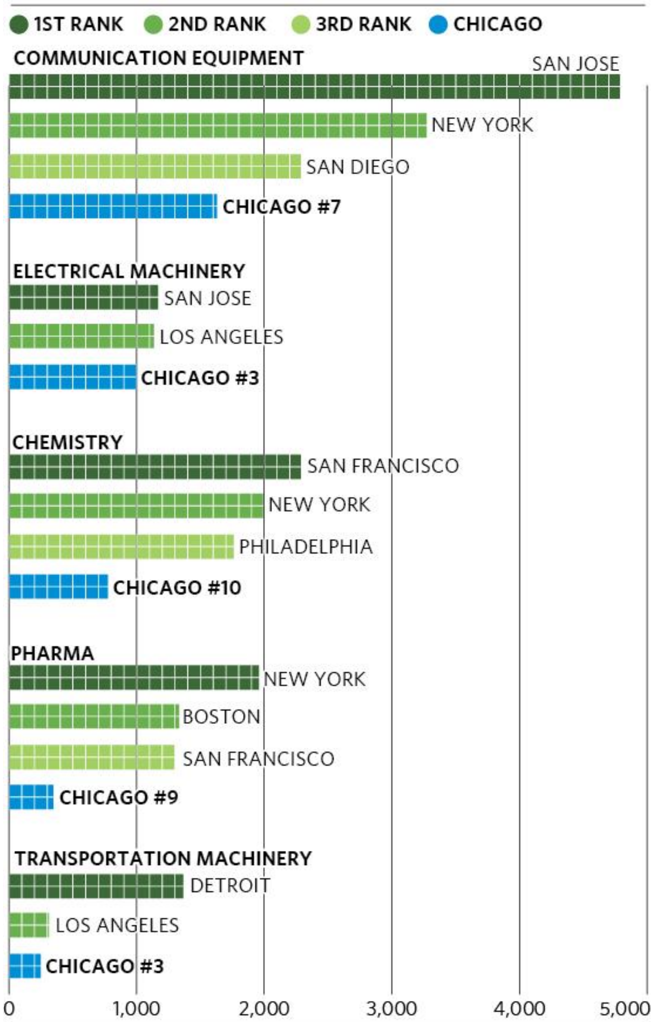
136 Angela Hardin, "LG Chem, Argonne sign licensing deal to make, commercialize advanced battery material" Argonne National Laboratory, January 6, 2011.

national lab assets and applied R&D efforts will better position the manufacturing cluster as a center of commercialization and innovation.

Technology Transfer and Private Research: Patent Output

Patents, one of the most common indicators of innovation, recognize intellectual property rights and grant market exclusivity for a limited period of time. Patents are widely used to gauge innovations in research that have commercial applications -- by prohibiting competitors from using a novel technology, patent holders hope to quickly commercialize and gain market penetration. While universities and national labs do hold some patents, overall the indicator best shows commercialization output by private firms: of all the region's patents over the past five years, only four percent come from universities or national labs, with the rest coming from private entities.

Figure 30. Chicago Region's Top Manufacturing Patent Technologies, number of patents, 2006-10



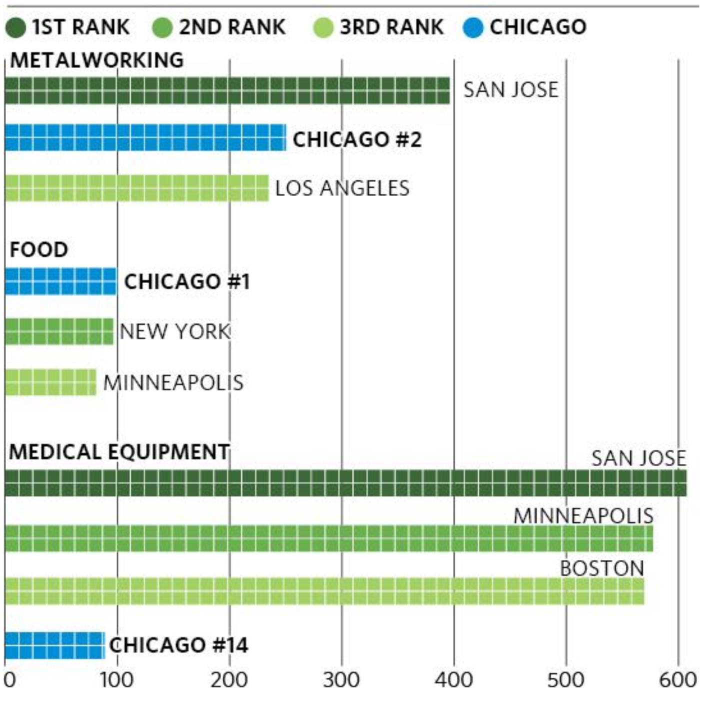
Source: CMAP analysis of USPTO data.

In the period 2006-10, individuals and firms in the Chicago tri-state region[137] received 12,440 patents, the seventh most among all domestic regions in this period. Since metropolitan Chicago is the nation's third largest economy, it underperforms on this innovation indicator, particularly in comparison to the regions with the most patent output, such as San Jose which received 40,446 patents in the same period. Total patents awarded within the Chicago region also serve as a reminder of the region's slip in innovation indicators. This chapter began by calling attention to the region's decline in R&D employment from second to eighth in the nation. Not surprisingly, as regional R&D employment has declined, so too has patent output, falling from third most in 1990 to fourth in 2000 to eighth in 2010.[138] Despite lower overall patent numbers, opportunities for the region exist within individual technology classes.

[137] Patent output is recorded by MSA. Accordingly, this section uses data for the Chicago tri-state region.

[138] CMAP analysis of U.S. Patent and Trademark Office data.

Figure 31. Further Manufacturing Patent Concentrations (in number of patents 2006-10)



Source: CMAP analysis of USPTO data.

Not surprising given the nature of Chicago's manufacturing cluster, patent output in the tri-state region is distributed across numerous industries. Some of the region's largest patent concentrations[139] in communication equipment, chemistry, pharmaceuticals, or medical equipment haven't kept pace with other metropolitan regions, while metropolitan Chicago is among the national leaders in electrical machinery, metalworking, and food. In several smaller categories the Chicago region ranked first in patent output. These include hardware, wire-working, and presses and printing, and correspond with strengths in private R&D expenditures. The region also led the nation in patents associated with freight, ranking first on railroad rolling stock, railroad draft appliances, and freight carrier accommodation. Though these industries patent much less than communications or electronics, they do play an important role in the region's innovation economy. The two line charts above display the region's largest manufacturing patent concentrations compared to the top domestic regions by technology.

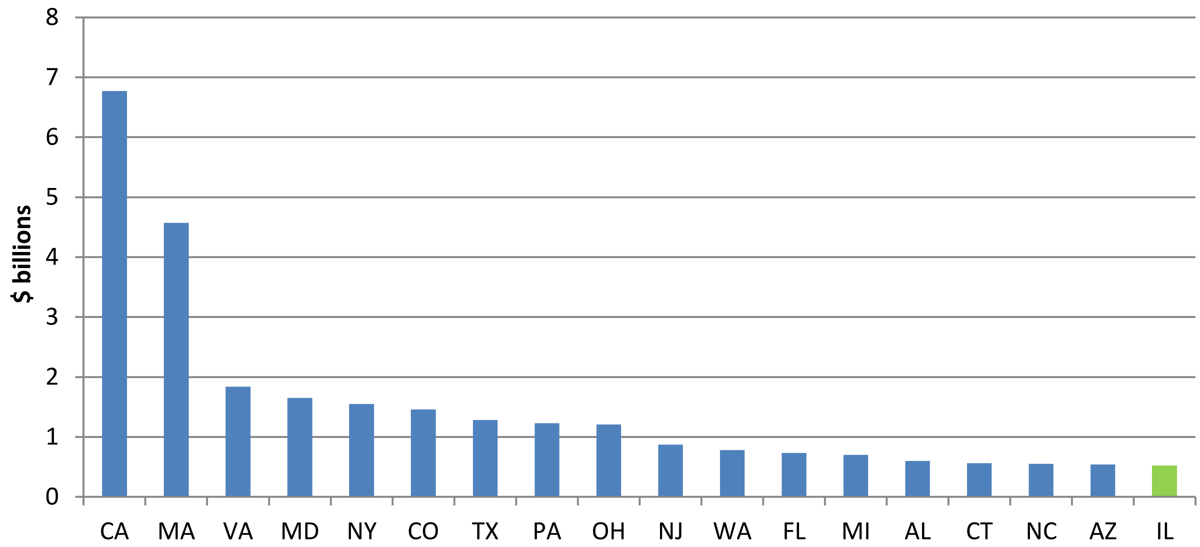
Innovation Challenge: Small Business Commercialization

Oftentimes it is the energy and creativity of small businesses that foster novel ideas into new start-up companies or products. As a state, Illinois seems to underperform in the commercialization of research from small firms, evidenced by the Small Business Innovation Research (SBIR) and its sister Small Business Technology Transfer (STTR) funds. These federal sources fund the R&D at small firms with the best commercialization potential through a highly competitive process. Successful recipients of these funds are widely recognized as leaders in small business commercialization. Since the inception of the SBIR and STTR programs, small businesses in Illinois have received $500,000,000 for cutting edge research with clear commercialization applications. This number however places Illinois 18th among all states, much lower than its population size, which is fifth.[140]

[139] This analysis includes those individual manufacturing technologies with at least 40 patents awarded in the region in the 2006-2010 period to show major regional manufacturing technologies.

[140] CMAP analysis of SBIR and STTR data.

Figure 32. Total SBIR/STTR Funding by State



Source: CMAP analysis of SBIR/STTR from 1983 to 2011.

The standing of Illinois compared to other states in the SBIR program suggests more can be done to help commercialize the next generation of transformative ideas within the region, especially since the vast majority of firms in the manufacturing cluster have fifty or fewer employees. For example, GO TO 2040 notes that prior to 2008, the State of Illinois provided matching grants to recipients of either SBIR or STTR. This program cost the state relatively little -- about $1 million per year for all of Illinois -- yet had substantial impacts on innovation.[141] Both Indiana and Wisconsin still offer matching grants; reestablishing this program in Illinois could demonstrate an increased commitment to manufacturing innovation.

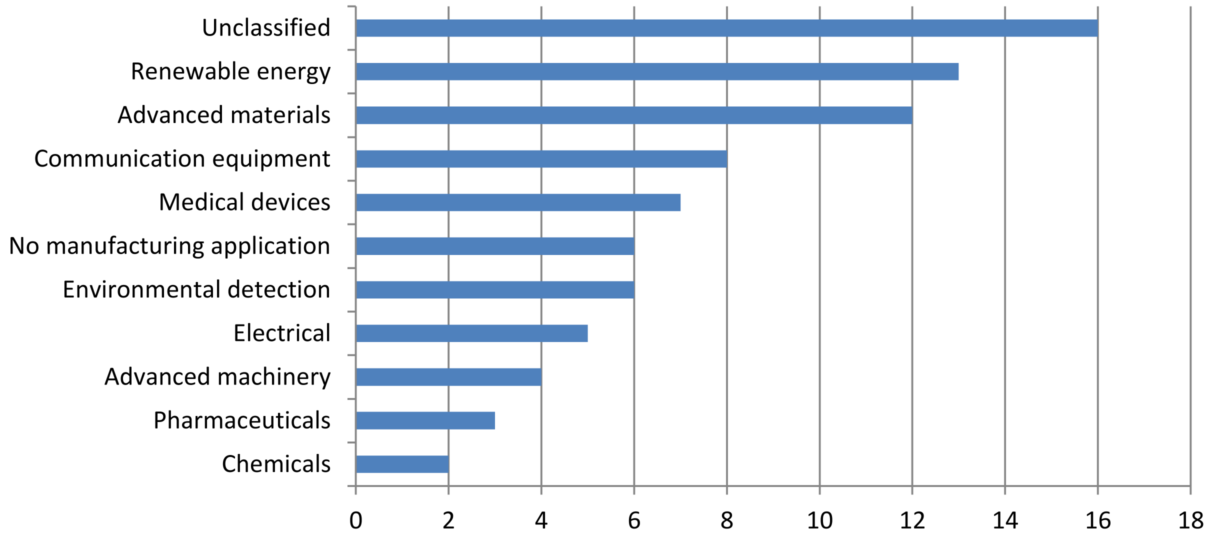
Looking at the most current SBIR data gives an indication of the types of innovation that a matching grant would support in the manufacturing cluster. Of the 82 awards in the CMAP region in 2011, six had no manufacturing applications, and another 16 were research whose relevance to manufacturing was still distant. The remaining 60 had more obvious manufacturing applications, demonstrating how manufacturing contributes disproportionately to the overall innovation economy. The following table lists awards by technology category, calling attention to capabilities in emerging manufacturing technologies.

The results of the SBIR analysis suggest innovation opportunities in the Chicago region and ways to overcome the gap between aptitude in basic research and commercialized products. Firms' SBIR research enhances core competencies of the regional innovation system, including renewable energy at the national labs or the life sciences at regional universities. The results also suggest that the region may be taking an active role in emerging technologies which may shape the future of advanced manufacturing such as nanotechnology and advanced materials.

[141] CMAP, "GO TO 2040," p.190-191.

Matched state funding of SBIR would help build on regional expertise in these areas and position the cluster for future growth.

Figure 33. 2011 Regional SBIR Awards by Research Category



Source: CMAP analysis of SBIR data.

Next Steps: Strengthening Innovation in the Cluster

A look at metropolitan Chicago's existing innovation infrastructure shows the region to have a large but slipping base. Compounding the relative decline in R&D employment and innovation indicators such as patents is the challenge of transferring advances in basic research into products with commercial value. To support the type of advanced manufacturing that leverages regional strengths yet also demands continuous product and process improvements, the region must focus on reestablishing the cluster as a leading center of manufacturing innovation. This includes increased technology commercialization, capabilities in emerging manufacturing technologies, R&D support for all firms in the cluster, and reoriented economic development strategies targeting manufacturing's dominant contribution to innovation.

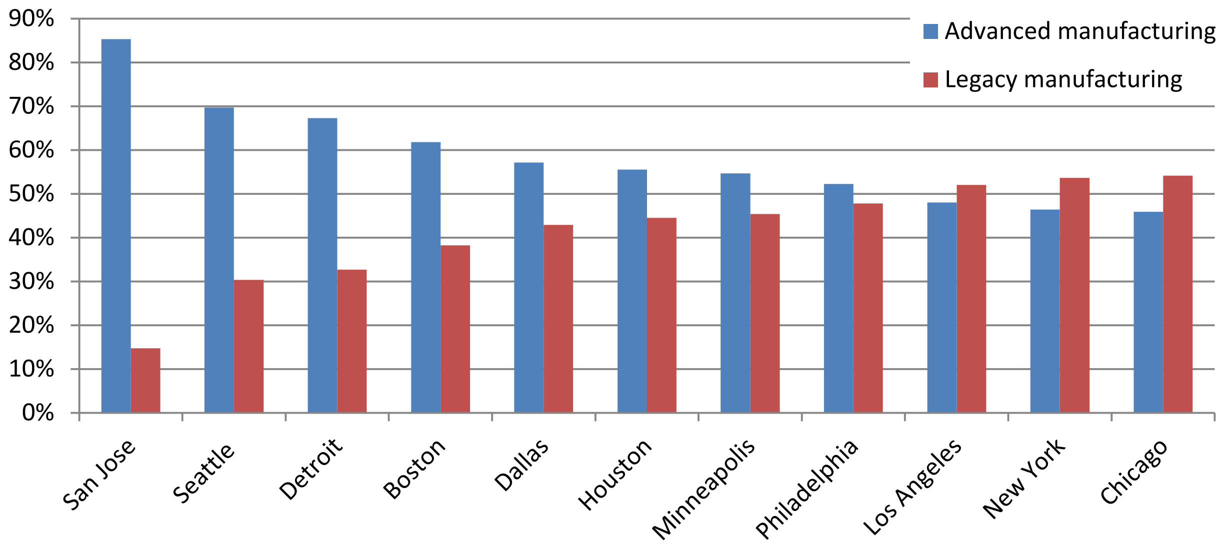
Increase technology commercialization to bridge the gap between the region's basic research assets and private market.

Metropolitan Chicago boasts incredible assets in basic research but like many other regions struggles in translating strengths into commercially viable products. Better integrating these drivers of innovation with industry will start to address the region's challenges in restoring private R&D. First, financing challenges remain after government R&D expires and before private firms feel comfortable investing. A clearer path to commercialization will give private firms a greater incentive to invest in research and one way to foster this would be requiring initial university-industry collaboration as a prerequisite for research dollars. Further work can be done too in improving information around available emerging technologies and connecting inventors to the business services necessary to turn a good idea into a thriving company.

Develop capabilities in emerging manufacturing technologies such as nanotech to capture the next generation of advanced products and processes.

CMAP's Advanced Manufacturing Scorecard illustrates how some industries are especially poised to be leaders in advanced manufacturing. Yet metropolitan Chicago's great manufacturing diversity means the region has a unique mix of all type of industries. Indeed, as the following graphic illustrates, the Chicago region has the highest proportion of any of the nation's top ten manufacturing centers in those manufacturing industries scoring lowest on the advanced manufacturing scorecard. As such, the region needs to focus on building capabilities in emerging manufacturing technologies that not only support advanced manufacturing industries but also help legacy industries better embrace product and process innovations.

Figure 34. Employment Distribution of Ten Largest Manufacturing Regions in 2011



Source: CMAP Advanced Manufacturing Scorecard. Manufacturing in other regions was categorized as advanced or legacy based on the criteria of CMAP's scorecard, not regionally-specific scorecards.

New material and process innovations highly applicable to specific regional concentrations include carbon fibers and additive manufacturing for the cluster's numerous fabricated metals and machining firms. Three technologies that have much wider applications across industries, and thus fit well into the region's diversified manufacturing base are IT, nanotech, and cleantech. Building regional expertise in these areas represents an opportunity to transition firms across the entire spectrum of the scorecard towards advanced manufacturing while enhancing regional competitiveness.

In February 2013, Governor Pat Quinn announced the creation in Chicago of an Illinois Manufacturing Lab. The lab will combine expertise and resources from the University of

Illinois, its National Center for Supercomputing Applications, and the private sector to help regional manufacturers build capabilities in computer modeling, simulation, and other elements of IT. As these technologies have broad applications across industries, the focus of the lab matches well with the diverse output of the manufacturing cluster, helping firms across a variety of industries better compete in advanced manufacturing. Still in its nascent stage, the region can benefit from this initiative and others that offer regional manufacturers more ways to utilize the "3P" characteristics of advanced manufacturing.

Provide R&D support, especially for region's small manufacturers, to better link the majority of the cluster to the innovation ecosystem.

About 85 percent of all manufacturing firms in the region employ less than 50 workers. These smaller firms are increasingly asked to not only produce but also design more components of a final manufactured good yet because of their size can devote fewer resources to R&D. Connecting small firms to the regional innovation system can help rebuild the cluster's R&D standing. Though numerous ideas abound about what this support would actually entail, one that has regional traction is a physical center offering concentrated services tailored to the innovation needs of smaller firms. By drawing on firms from across the region, the center can offer collectively what one firm alone couldn't afford. As individual firms operate highly specialized machinery and processes unique to their enterprise, the center should focus on cross-cutting technologies and process with applications across numerous industries, such as the proposed Illinois Manufacturing Lab mentioned above.

Reorient economic development strategies toward the cluster to capitalize on manufacturing's dominant contributions to innovation.

Metropolitan Chicago's manufacturing cluster has long been a cornerstone of the regional economy. Not only does the cluster provide quality jobs and supports interrelated industries, it also fuels innovation in the region and the state. CMAP's Advanced Manufacturing Scorecard illustrates some industries within the region's manufacturing base especially poised to be leaders in innovation. Due to metropolitan Chicago's great manufacturing diversity, the region has a unique mix of all types of industries. Rather than emphasize direct competition with other global regions' strengths, our region would be better served by focusing on its own advanced manufacturing specializations. While other regions may over-specialize in a single field, the broad output of metropolitan Chicago enables it to draw on strengths across multiple industries.

Regional manufacturing specializations poised to flourish in 21st Century manufacturing include health sciences; chemicals, plastics, and rubber; and fabricated metal. In machinery -- the region's largest sector -- the cluster manufactures less in automotive and aerospace industries compared to highly specialized regions like Seattle or Detroit yet remains among the national leaders in the electrical and industrial equipment that leverages strengths of the freight cluster. And though the computer/electronics sector scores well on the advanced manufacturing scorecard, the region's under-specialization in this high-tech field suggests it may be hard-pressed to out-compete other global electronics centers that have highly developed clusters. While recognizing that diversity of output has long been a great asset of the cluster, the region can reorient economic development strategies to target those industries whose developed regional supply chains, strong customer relationships, and balanced production/research output best maximize the manufacturing's dominant multiplier effect.

Workforce

As technology continues to remake the factory floor, the demands on the manufacturing workforce will evolve dramatically. An adaptable and skilled manufacturing workforce is essential for the region to reverse the recent downward trend in employment and increase the manufacturing cluster's productivity. Advanced manufacturing has changed the workforce landscape in dramatic ways -- today's production processes require higher-skilled, technologically savvy workers that can adapt quickly to new demands. Attracting students to manufacturing careers is challenged by a lingering perception that this cluster offers little opportunity for advancement and high-wage jobs. Furthermore, retraining workers for emerging manufacturing technologies and processes is expensive and requires investment by the worker, employer, and training provider.

While retooling the manufacturing workforce is a major challenge for the region, it is also an opportunity given the assets that can be brought to bear. Metropolitan Chicago remains home to world-renowned education and research institutions, and the region attracts talent from across the country. A large network of workforce development organizations, community colleges, and local governments are also working to reconstruct the manufacturing workforce pipeline. There is real potential to move workers into high-skilled jobs that will drive the future of the cluster, and collaborative public-private partnerships are underway to establish these strategic systems. This chapter analyzes the occupational needs and explores the workforce challenges and opportunities facing the region's manufacturers.

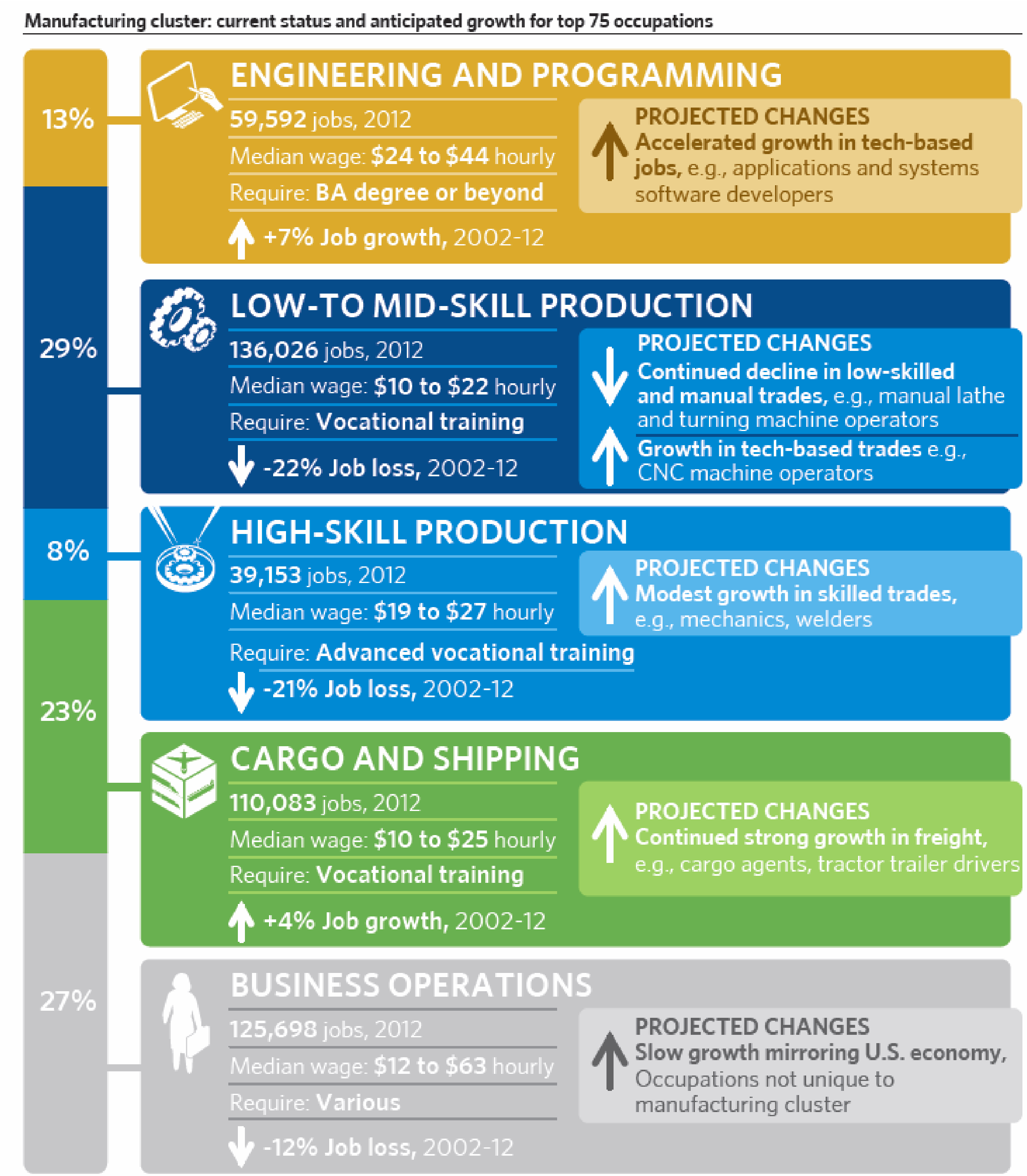
Metropolitan Chicago's Manufacturing Workforce

The manufacturing cluster employs a broad array of workers -- from people who pack boxes at the end of an assembly line to doctors who conduct research to executives who oversee operations in today's complex global marketplace. To understand the recent changes in the workforce, as well as the current and future needs of the cluster, CMAP conducted an analysis of its occupations. This job-level data enables an understanding of the cluster's move towards more advanced processes and products. Decreases among lower-skilled and manual jobs are expected to continue as those occupations are automated out of the workforce. On the other hand, growth is expected in the higher-skilled, technology-based occupations.

Occupational Analysis

While the manufacturing cluster consists of over 650 unique occupations, 75 percent of the jobs are in just 75 occupations. For the purposes of this analysis, CMAP focused on this 75 percent, and all numbers that follow refer to this component of the larger manufacturing cluster. These occupations are grouped into four categories: 1) engineering and programming, 2) production (subcategorized by low- to mid-skill and high-skill production), 3) cargo and shipping, and 4) business operations and support. The following section describes important characteristics of each of these categories, including trends, wages, and education and training needs.

Figure 35. Cluster Occupational Analysis Summary



This graphic shows key characteristics of 75 percent of the manufacturing cluster's employment, organized by the four major occupational categories. The chart shows several data points for the largest occupations in that category: 2012 range of hourly median wages, employment change from 2002-12, and 2012-22 employment projections and openings. Openings reflect retirement and turnover projections in each occupation. The graphic also describes training requirements for each occupational grouping. Vocational training, required for Production and Cargo and Shipping occupational categories can take place on the job or in a variety of academic or community-based training settings.

Engineering and Programming Occupations

In 2012, there were 59,592 jobs in the cluster's engineering and programming category, comprising nearly half of all the region's jobs in these occupations. There are 11 specific occupations in this group, including computer programmers, network and computer systems administrators, mechanical engineers, and industrial engineers.

Trends

Engineering and programming occupations are the only category that grew as a whole over the last decade, adding 3,703 jobs, a seven percent increase. Growth is projected to accelerate rapidly; EMSI estimates an additional 15,000 new jobs will be created between 2012-22, approximately a 25 percent increase, due to changes in the economy. This trend reflects the cluster's demand for higher skilled workers with sophisticated mathematics and computer skills. In addition, EMSI projects more than 20,000 openings due to turnover and retirement between 2012- 22.

The bulk of these workers are in the support segment (which includes R&D, testing labs, and design services) and the more advanced core industries of the cluster, and these are projected to see significant growth over the next ten years. Computer systems design services was the fastest changing industry, adding more than 6,500 jobs over the last decade, a 75 percent increase.

Employment Projections

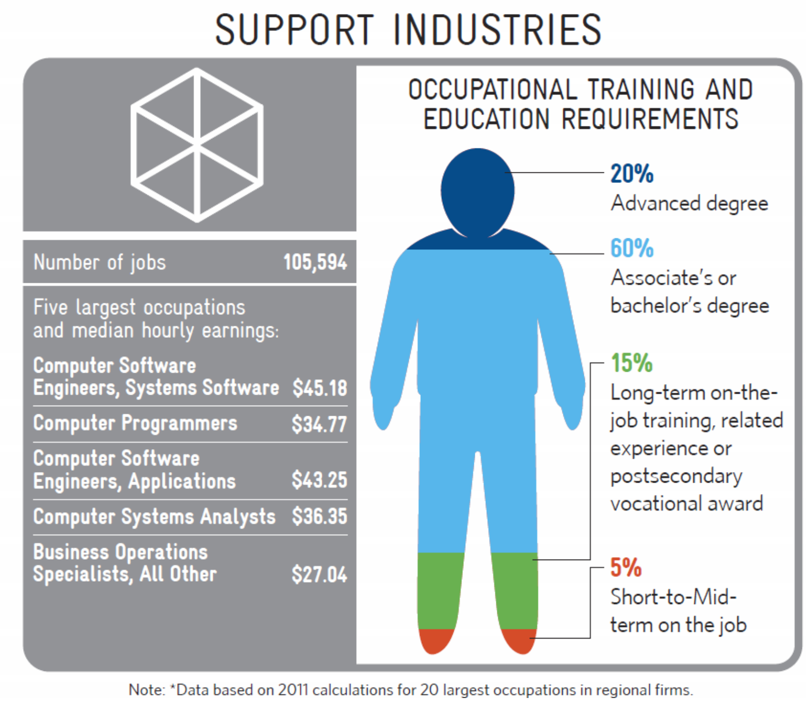
For the purposes of this occupational analysis, CMAP has used EMSI software, whose methodology utilizes historical data to create future trend lines. EMSI creates projections by combining data from the U.S. Bureau of Labor Statistics' Quarterly Census of Employment and Wages, Current Employment Statistics, and Staffing Patters. These kinds of projections are simply one tool for understanding future economic trends and should not be viewed as predictions; CMAP has also interviewed a number of employers and other experts in the manufacturing field to understand the future direction of workforce needs. For the complete data on EMSI projections, see http://go.usa.gov/4NXh.

Wages and Education

Advanced processes and procedures deployed in core manufacturing industries are requiring engineers and programmers to develop computerized systems that increase automation and efficiency in the production process and supply chain. As a whole, these are some of the highest paying jobs in the cluster, and ten of the 11 occupations have median hourly wages of more than $31. Engineering and programming jobs typically require at least a bachelor's degree. The figure that follows highlights the five largest occupations in the cluster's support industries, the majority of which are programming and engineering occupations.

Production Occupations

Figure 36. Top Occupations in the Support Industries of the Manufacturing Cluster



This infographic illustrates the occupational make-up of support industries. Computer programming and related occupations make up four of the top five occupations in support industries. This is an area of growth in the cluster providing key tech-based services for the core as it moves towards developing more advanced processes and products.

Similar infographics covering each of the cluster's core industries are available on CMAP's website at http://cmap.illinois.gov/policy/drill-downs/manufacturing/.

Production workers conduct the core work of the manufacturing cluster, transforming raw materials into every type of good from electronics to books to bread to heart medication. There are 29 unique production occupations in this category. For the purpose of this analysis production workers are divided into two subcategories: jobs requiring short-to-moderate term vocational training either on-the-job or through a program are categorized as low- to mid-skilled workers; and jobs that require advanced training and long-term experience are categorized as high-skilled production workers.

Trends

Production jobs in the cluster shrank from 221,244 jobs in 2002 to 175,179 jobs in 2012 -- a 21 percent decrease, and the low- to mid-skilled production category lost 37,836 jobs, a 22 percent decline. This decline is expected to continue at a significantly slower rate -- EMSI projects these occupations could lose around five percent in the next ten years. The magnitude of these losses has differed across industries. For example, paper and printing industries have experienced significant contractions, and printing press operators declined by 33 percent, or 3,391 jobs over the last decade. This industry is also expected to lose more than 20 percent of its workforce by 2022.

Although high-skilled production occupations declined by 8,229 jobs, roughly 17 percent in the last ten years, this trend is expected to change course. On the whole, higher skilled occupations are expected to grow approximately two percent between 2012-22. Included in this growth, industrial machinery mechanics are projected to add over 700 jobs, more than a 15 percent increase. Welders are also expected to add nearly 500 jobs in the coming decade, roughly a ten percent increase.

In addition to projected job gains or losses due to changes in the economy, openings due to retirement and turnover will also require new workers. From 2012-22, there will be approximately 35,000 openings in low- to mid-skill occupations and 10,000 openings in high-skilled production occupations.

Education and Wages

Production occupations require a broad spectrum of skill levels, from workers who pack boxes, a task they can learn in a matter of hours, to tool and die makers or industrial mechanics whose trades take years to learn. For the most part, production occupations currently rely on less formal on-the-job type training that can be supplemented with training programs offered by community colleges or other training providers. All but one of the top 29 production occupations requires on-the-job training rather than formal post-secondary degree; welding is the only occupation currently requiring certification. Training for production jobs will be discussed at length later in this chapter. Median hourly pay among the low- to mid-skilled workers ranges from roughly $10 to $22, with most occupations earning around $16. Among the higher-skilled occupations, median hourly pay ranges from $19 to $27. First-line supervisors of production and operating workers earn the highest median hourly salary of over $27.

Cargo and Shipping Occupations

Freight-related occupations are highly concentrated in the region and are an important strength for the economy as a whole. In 2012, there were 110,083 cargo and shipping jobs within the cluster's top 75 occupations. Eleven discrete occupations are in this category, many of which are concentrated in the customer and supply industries of the cluster. These occupations are integral to the region's competitive advantage in freight transportation relative to other manufacturing centers around the country.

Trends

Cargo and shipping occupations were a source of growth amid the past ten years of overall decline in the cluster. Many of the jobs, like truck drivers or rail engineers, are particularly resistant to the outsourcing observed in other areas of the cluster. The number of rail conductors and yard masters, as well as locomotive engineers increased by over 35 percent over the last decade, adding 660 and 624 jobs, respectively, between 2002-12. The heavy tractortrailer driver occupation increased by 28 percent, adding 10,383 jobs to the region; this occupation is expected to grow at a similar pace in the coming ten years. Cargo and freight agents added more than 1,500 jobs, a 43 percent increase. However, a related occupation, shipping, receiving, and traffic clerks, lost nearly 3,000 jobs, a 29 percent decrease from 2002-12; these are jobs that could have been particularly vulnerable to reduction because of automation in a decade of vast advances in communications and information sharing.

Wages and Education

Shipping and logistics occupations, similar to occupations in production, require on-the-job training rather than education institution-based training. Median hourly wages range from less than $10 for people who package products by hand to $25 for rail conductors and yard masters. Most of the 11 occupations in this segment have a median hourly salary of above $16.

Business Operations and Support Occupations

In 2012, there were 125,698 jobs within the management, business operations, and support occupations within the cluster's top 75 occupations. These include 24 unique occupations, many of which are important to nearly all types of businesses in the region -- from chief executives to janitors to sales representatives. Most of the occupations included are not unique to the cluster, nor are they concentrated in it. The occupations are responsible for overseeing or assisting in the businesses' daily operations, as well as long-term growth strategy and business development.

Trends

The number of jobs in this category declined by 12 percent over the last decade. These occupations are not unique to the cluster and projections are expected to be aligned with the slow rebound of the economy; modest growth is projected by EMSI over the coming decade.

Wages and Education

Business operations and support occupations are among the highest paying in the cluster -- 19 occupations have median hourly earnings higher than $22. Chief executives earn the most with over $60 median hourly wages and janitors earn $12 per hour. Occupations in this segment involving management require bachelor's degrees and related work experience. Other entry-level occupations require on-the-job training.

Workforce Challenges and Opportunities

Across production, engineering, and administrative occupations, requisite skills have evolved to reflect new demands of advanced manufacturing. The up-skilling of the cluster affects not only incumbent workers, but also the training future workers will need for a successful manufacturing career. Compounding the issue, many of manufacturing's most skilled workers will soon retire, while lingering perceptions limit the pipeline of available new workers. This section explores workforce challenges and opportunities in the regional cluster, showing how this new era of advanced manufacturing requires different skills than jobs of the past, but it also holds promise for a dynamic career path for the next generation of workers.

Workforce Challenge: Aging Workforce and Recruitment

In the next ten to 15 years the region will lose up to 40 percent of its core manufacturing workforce to retirement.[142] These workers have spent decades learning and improving their trade, becoming expert machinists, tool and die makers, and countless other occupations. Since much of manufacturing is firm specific, seasoned workers can also serve as instructors on the factory floor, teaching the newer generation of workers not only how to operate firm-specific machinery, but also to problem solve and look for process improvements.

Lingering perceptions around manufacturing have limited the pipeline of new manufacturing workers, so the retirement of the current skilled generation will lead to some loss of accumulated knowledge -- employers find themselves in the unfortunate position of having retirees leave before they can share their knowledge and experience with the next generation. Recruitment issues that have curbed young worker enthusiasm in manufacturing careers include perceptions, outsourcing, and compensation.

Perception

Employers recount that misconceptions distort how prospective workers view the cluster. Many shy away from manufacturing due to lingering perceptions that suggest factory jobs are dirty, brawny, menial, and vulnerable to outsourcing.[143] Job loss this past decade especially has led many parents and guidance counselors to suggest students earn a bachelor's degree and pursue careers elsewhere. However, this framing of manufacturing reflects the manufacturing of the past, not the future: While misconceptions persist, manufacturing has moved on. The viable opportunities to develop high-demand skills and career ladders remain widely unknown among parents, students, and counselors. And the "dirty factory" of the past has been replaced with innovative and cutting edge technology. Finally, compared to other clusters, manufacturing still tends to pay higher wages, and, importantly, offer benefits to its workers.[144]

Outsourcing to Temporary Help Workers

Many workers have been reluctant to enter manufacturing because of past job loss. While core production employment in metropolitan Chicago's manufacturing cluster certainly fell the past decade, some of this loss may be overstated because of an increased use of temporary workers. In response to competition and global shifts, many manufacturing firms have turned to temporary help to expand production without commitment. If hired through a staffing agency, these workers are counted under employment services, not manufacturing. As such, official manufacturing statistics can undercount actual production workers.

Though temporary workers are not a new component in the manufacturing workforce, the degree of their utilization has accelerated. In 1989, an estimated 2.5 percent of national

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[142] Interview with Dan Sweeney, "What Happened to American Manufacturing?," *Afternoon Shift*, WBEZ, Aired November 2, 2012.

[143] Willy Shih, "Just How Important Is Manufacturing?" Harvard Business Review Blog, February 21, 2012.

[144] John Markoff, "Skilled Work, Without the Worker," New York Times, August 18, 2012. Data on average weekly hours and overtime from the Bureau of Labor Statistics.

manufacturing employment came from temporary workers; by 2006, this rose to 9.2 percent.[145] The economic uncertainty of the recent recession likely accelerated this trend; CMAP found that up to eight percent of the workforce could be employed through temporary help services in 2012. Temporary help workers are less likely to receive benefits and the advanced training for career mobility, a further workforce challenge for the region.

Compensation

Core manufacturing industries were once seen as a promising vehicle for many low- to-mid skilled workers to achieve the middle-class income and stability. However, the U.S. manufacturing workforce has shrunk significantly in the past decade, and as new jobs become available, the low entry-level wages may not match the skills demanded.[146] There is growing discussion among labor economists that production wages have not kept pace with the higher skills levels required of workers.[147] Although on the aggregate, manufacturing jobs pay more than others in the regional economy, low pay for these entry-level jobs could compound the region's recruitment challenge.

Many entry-level jobs in manufacturing pay low starting salaries and these workers may not be aware of the career pathways to earn higher incomes. For example, team assemblers present in a number of core industries start at $11 per hour. Jobs that only require a high school diploma outside of the cluster often initially pay more. For instance, a shift-manager at a fast food restaurant may begin at $15 per hour.[148] However, that pay can quickly plateau while manufacturing workers can develop more valuable skills to work on more complex machines and processes in production to increase their compensation that would quickly surpass their fast-food equivalents.

Workforce Challenge: Skills Gaps

Skills gaps impact firms at every level. In the near term, employers require trainable workers and those with some production skills. Some of these particular shortages may become more pronounced over the next several years, particularly among higher-skilled production, engineering, and computer programming workers. Additionally, policy barriers like federal immigration laws impede manufacturers' ability to hire and retain the labor they need on the factory floor or in the labs, as well as the region's ability to retain inventors and entrepreneurs.

Production Skills Shortages

Regional employers report an inability to find and retain production workers.[149] Shortages of production workers can be immediately felt on a factory floor, and when machines go unused, firms cannot reach their full output capacity. These shortages are due to a variety of factors,

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[145] Matthew Day, Susan N. Houseman, and Anne Polivka, "Manufacturer's Outsourcing to Staffing Services," ILR Review, Vol. 65, No.3, 2012

[146] Adam Davidson, "Skills Don't Pay the Bills," New York Times, November 20, 2012.

[147] Bill Testa and Paul Traub, "Wage growth in the Seventh District's manufacturing occupations," Blog: Bill Testa on the Midwest Economy, September 7, 2012.

[148] Davidson, November 2012.

[149] CMAP interviews, with the Valley Industrial Association, Chicago Cook Workforce Partnership,

principally retirement, difficulty recruiting new workers to the field, and economic factors including low entry-level pay for demanding jobs. Interviews with workforce training providers, employers, and industry support groups provided anecdotal evidence of several acute shortages, due to retirements and increased demand for certain goods. Many tradespeople nearing retirement once entered factories as low- and mid-skilled workers and then spent decades honing their abilities. Now and in the future, factories will need workers who bridge the gap between deep mechanical knowledge and computer-based technology.

Several acute shortages among production workers pose immediate challenges for the cluster. [150] The region could lose up to 40 percent of the cluster's core workforce in the next ten to 15 years to retirement.[151] These workers have spent decades learning and improving on their trade, and a dearth of skilled production workers can cripple manufacturers' abilities to keep up at a time when demand for products is growing, let alone innovate. [152]

Jobs in production can be difficult to fill. The manufacturing workforce requires the skills necessary for any modern workplace: reading, writing, math, and computer operation. In addition, firms must be discerning because it is much more expensive to train employees for production than in other sectors. The machinery used in production can cost tens of thousands to millions of dollars. Safety is also a foremost concern. Employers need to have some confidence that a worker is fit to competently and safely do his work, and that costly training will yield results in added productivity. Furthermore, these employers require reliable workers who consistently show up on time and follow instructions from a manager.

Immigration and the Cluster

Manufacturers have long employed immigrants in metropolitan Chicago -- a 2003 survey found that 35.3 percent of all manufacturing industry workers were foreign-born.[153] Immigrants have long played important roles in manufacturing -- from entrepreneurs to inventors of new products and processes to laborers and truck drivers. Increasingly complicated immigration laws have impacted the cluster's labor pool. The National Association of Manufacturers (NAM) has called for reform of immigration laws on the grounds that they impact the sector's competitiveness. The organization posits that current policy creates constraints for employers, causes increased administrative burdens, and does not function as an effective deterrent of illegal actions.[154] In short, current federal immigration policy hinders the cluster's ability to attract and retain the talent and labor necessary for the growth of more advanced manufacturing.[155]

[150] Data on worker shortages is limited by the fact that manufacturers, particularly small and medium-sized manufacturing firms use informal networks or means to recruit workers; it is difficult to track openings in particular jobs across the region.

[151] Interview with Dan Sweeney, "What Happened to American Manufacturing?," *Afternoon Shift*, WBEZ, Aired November 2, 2012.

[152] Harold Sirkin, Michael Zelner, and Douglas Hohner, "Made In America, Again," Boston Consulting Group, 2012, p. 10.

[153] Rob Paral and Michael Norkewicz, "The Metro Chicago Immigration Factbook," Institute for Metropolitan Affairs at Roosevelt University, June 2003.

[154] Christine Scullion, "Immigration Reform," National Association of Manufacturers.

Machining Skills

As manufacturers implement advanced processes, develop more advanced products, and provide greater customization, they will need workers who can adapt to these rapid changes. Presently, employers around the region face some acute shortages. Subtractive manufacturing, where Computer Numerically Controlled (CNC) machines cut away and sculpt material, remains a foundational step in the production process. The sculpted object could be the end product, a component, or a mold for making another piece. CNC machines now dominate factory floors, but many of the workers most experienced on these machines are approaching retirement; furthermore, these machines are getting increasingly sophisticated.[156] Even the lowest level workers must have a basic understanding of the principles of diverse materials including metals and plastics; the capacity to identify mechanical problems; the ability to communicate clearly in writing; reading comprehension for written directions; and mathematic reasoning used in blueprints.[157] These jobs require astute problem solving, the ability to work as a part of a team, and fastidious attention to details.

Welding

Welders are also in high demand because of both openings and firm expansions throughout the region.[159] This trade requires craftsmanship, mathematical reasoning, and knowledge of physics and chemistry associated with metals, gases, and heat. Welders have to adapt to automation in the workplace too. Technological advances in welding have slightly lagged other manufacturing, but robotic welding is becoming increasingly common in factories.[160] Whether a welder is programming a robot or doing the welding herself, he or she must still have a mastery of science, mathematics, and craft in order to properly operate the machine. Welding occupations are often a first step on a pathway to a high paying, high skilled manufacturing production career.

The average age of most people working in these high-tech jobs in manufacturing is in the 50s. There's really not been a lot done to make sure that there's a younger generation ready to step into the shoes of these guys who are near the end of their careers. -- Jeff Owens, president of Peoria-based Advanced Technology Services[158]

Maintenance

Machine maintenance technicians are critical workers on a factory floor, and the demand currently far exceeds the supply.[161] Factories need workers who can anticipate maintenance needs, assess malfunctioning parts, and make repairs. As equipment evolves, manufacturers need to upgrade the skills of their incumbent maintenance technicians. To repair the computer-based machines, maintenance workers must be equipped with the mechanical abilities, as well as the computer-literacy, required to run and read electronic diagnostics.

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[155] Vivek Wadhwa, "America's Immigrant Brain Drain," Bloomberg Businessweek, March 4, 2009.

[156] Jill Jusko, "Training the Manufacturing Workforce: Don't Go It Alone," Industry Week, May 14, 2012.

[157] Davis Jenkins, "Career Pathway Planning Guide," University of Illinois at Chicago.

[158] Robert Channick, "Manufacturing Building a Bigger Presence in the US," Chicago Tribune, June 4, 2011.

[159] CMAP interview with Valley Industrial Association.

[160] Madeline Novey, "Shortage of Welders Sparks Interest in Training," The Fort Collins Coloradoan, 10/21/2012.

[161] CMAP interviews, various.

Demanding Skills for a Manufacturing Workplace

Each of these production occupations is within reach for many workers because they require vocational training, on-the-job training, and experience rather than a bachelor's degree. However, employers continue to cite lack of "soft-skills" as a major impediment to finding qualified workers, even for entry-level jobs. Workers must have an aptitude for computer-based machinery and other current technology, and they must acquire new skills as technology changes. This is now essential to many production industries and other areas of the cluster including freight, logistics, and supply chain management.

Reading comprehension and a variety of mathematics skills -- such as algebra and trigonometry -- are also required for computer-aided production. The incumbent workforce of CNC machinists, welders, and mechanical technicians need additional training for more technologically-based machinery.[162] It is no longer enough to read and interpret blueprints; increasingly, workers need to be able to use computer-aided design (CAD) software to manufacture a new piece.[163] Unless workforce training strategies change to address the lack of a qualified pipeline of production workers, these acute shortages are expected to persist.[164]

Soft-Skills

Even though the prerequisites are minimal, a recent national study showed that 20 percent of employers cited a lack of soft skills as the key reason they couldn't hire a prospective employee.[165] Entry-level employees in the cluster need to be reliable, have the capacity to solve problems, and possess adequate communication skills.[166] Firms throughout the region reported not being able to find employees with the basic skills to do rudimentary tasks.[167] This is a challenge because nearly 45 percent of the jobs in the cluster require only short-to-medium term training. That proportion is much higher in some of the region's other industries -85 percent in food and beverage, 75 percent in primary metals, or 70 percent in fabricated metals.[168] Employers are looking for low-skill workers who will be able to provide returns on the company's investment of time and training expenses. Whether a manufacturer hires an outside instructor to conduct the training or uses its own employees to lead training in-house, it is costly. Training can be costly for manufacturers either because of the direct expense or the productive hours foregone when a skilled worker has to set time aside to instruct trainees. [169]

[162] Tom Morrison et al, "The Manufacturing Skills Gap," Deloitte Consulting LLP and The Manufacturing Institute, 2011, pg. 9.

[163] Ray Prendergast, "America's Manufacturing Boom Could Be a Bust Without Right Education," Huffington Post, 8/22/2012.

[164] Ray Prendergast, "America's Manufacturing Boom Could Be a Bust Without Right Education," Huffington Post, 8/22/2012.

[165] "Talent Shortage Survey," Manpower Group, 2012.

[166] Nick Schulz, "Hard Unemployment Truths About 'Soft' Skills," Wall Street Journal, September 19, 2012.

[167] Chicago Manufacturing Renaissance Council, "Closing the Gap, Surpassing the Competition: City Colleges of Chicago, Manufacturing, and International Best Practices," Prepared for Cook County, 2006.

[168] EMSI data, CMAP analysis.

[169] Paul Downs, "Why Training Workers Costs More Than You Think," New York Times, December 4, 2012.

Today entry-level manufacturing workers are expected to have little formal training beyond a high school degree, although this will change in the future as technology replaces many basic tasks on a factory floor. The type of contextual, soft-skills training programs needed to prepare entry-level workers for these careers are available in the region. However, some challenges remain. It takes many months to acquire the necessary skills to enter a firm at a more advanced level.[171] Furthermore, many companies prefer to evaluate the workers' abilities over a period of time before placing workers at their levels of training. With renewed demand for production workers in the manufacturing core, there may be an opportunity to expand preparation and training opportunities like apprenticeship.

A National Strategy to Improve Global Competitiveness

In June 2011, President Obama announced the creation of the Advanced Manufacturing Partnership, a national strategy to promote development of technology critical to the future of manufacturing. The partnership strengthens relationships between education institutions, industry leaders, and government. Specific activities include the National Network for Manufacturing Innovation (NNMI) and the Advanced Manufacturing Jobs and Innovation Accelerator Challenge.[170]

Engineering and Scientists

Engineers and scientists are part of the intellectual backbone of manufacturing. And while the Chicago region attracts many graduates with the relevant science- and math-based degrees, the U.S. is not keeping pace with our global competitors. By 2010, only 4.5 percent of bachelor's degrees awarded in the U.S. were in engineering, as compared to 12 percent in Europe, and 21 percent in China and Japan.[172] Engineering will also be negatively impacted by the wave of baby boomer retirements; unless more workers pursue engineering degrees, shortages are expected to grow.[173]

Engineers and scientists are especially important to manufacturing as these occupations are key to the growth of nascent advanced industries like nanotechnology. Several initiatives have set out to attract and train more engineers and scientists. The National Science Foundation (NSF) projects that six million nanotechnology workers will be needed worldwide by 2020, with two million of those jobs in the U.S.[174] As the field grows, companies will rely less on workers with PhDs and more on suitably trained technicians, with masters, bachelors, and associates degrees.[175] In order for this industry to grow in the region, companies will have to find a skilled workforce that can produce these new technologies for marketable costs.

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[170] "From Discovery to Scale-up: About the National Network for Manufacturing Innovation," Advanced Manufacturing National Program Office, 2012.

[171] Chicago Cook Workforce Partnership, "DCEO WIF Partner Information Session," January 17, 2013.

[172] Charles Vest, "Engineers: The Next Generation," Academy of Engineering of the National Academies, October 16, 2011.

[173] "Why is Workforce Development Important?" Society of Manufacturing Engineers, 2012.

[174] Mihail Roco, "The Long View of nanotechnology Development," National Science Foundation, February 2011, pg. 429 .

[175] "Education," National Nanotechnology Initiative, nano.gov.

Management and Business Operations

Eighty-three percent of the region's manufacturers are smaller companies with less than 50 employees. Nationally, 78 percent of manufacturing firms are family-held and held by a very small group of investors.[176] When the owner retires, that departure can have profound implications on the company.[177] Nearly 70 percent of manufacturing chief executive officers, primarily of small companies, are expected to retire in Illinois in the coming 15 years. Small and medium-sized firms need to develop succession plans in order to prevent a disruption, or at worst, closure of a company.[178] This challenge also presents an opportunity for new leadership and innovative approaches. Some resources are available; currently, the Illinois Manufacturing Extension Partnership's program trains professional advisors to work with family-businesses about strategies to ensure a smooth transition.[179]

Workforce Opportunity: Training the Cluster's Workforce

Metropolitan Chicago's manufacturing cluster must be supplied with a skilled workforce that can craft the next generation of products or processes. Work is already underway to identify needs among employers and partnerships are forming to train future workers, upgrade incumbent workers' skills, and raise awareness on the types of jobs advanced manufacturing provides. At the same time, the current workforce system can be cumbersome and inaccessible for employers to access their services.

These aren't stereotypical factories anymore. It's high-tech manufacturing using state-of-the-art equipment that requires good math and computer skills as well as critical thinking. -- Ken Ender, President of Harper College[180]

Since manufacturing greatly impacts the rest of the economy, training for manufacturing has become a policy priority in recent years at the federal, state, and local levels. Recently, Palatine's Harper College was awarded $12.9 million in federal funds to expand its advanced training program to colleges across the region.[181] Numerous other opportunities are expected to support manufacturing throughout the country, and a number of federal agencies have partnered or issued grants to target the manufacturing workforce.[182] [183]

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176 U.S. Census Bureau for NAICS 31-33.

177 "Seventeen IMEC Manufacturing Specialists Earn Family Business Advisor Certification," Illinois Manufacturing Extension Partnership, November, 1, 2012.

178 CMAP interview with the Chicago Manufacturing Renaissance Council.

179 IMEC, November 1, 2012.

180 Quoted in, "Innovative Harper College manufacturing program spreading statewide," Kimberly Pohl, Daily Herald, September 20, 2012.

181 Kimberly Pohl, "Innovative Harper College manufacturing program spreading statewide," Daily Herald, September 20, 2012.

182 Those agencies include: U.S. Department of Commerce's (DOC) Economic Development Administration; the DOC's National Institute of Standards and Technology's; Hollings Manufacturing Extension Partnership; the U.S. Department of Energy's Advanced Manufacturing Office; the Department of Labor's Employment and Training Administration; the Small Business Administration; National Science Foundation; and Small Business Innovation Research.

183 "Advanced Manufacturing Jobs and Innovation Accelerator Challenge," Grants.Gov, May 24, 2012.

Incumbent Worker Training

A growing number of the skilled workers already in the workforce will need supplemental training to translate their skills to the technological and process innovations in an advanced manufacturing setting. Larger firms tend to be able to develop and maintain their own continuous worker education, but smaller firms can be challenged to keep up with the technology in their fields. Fortunately, the region does have in place some existing support strategies to retrain incumbent workers. Both the Illinois Manufacturing Excellence Center and the state's Employer Training Investment Program (ETIP) have offered opportunities for employers to upgrade workers skills. This enables the employers to retain knowledgeable workers while ensuring their operations remain competitive. A vast network of stakeholders aid manufacturers around the region to upgrade workers' skills for changing technologies and processes. These stakeholders include community-based organizations, education institutions, industry associations like the Tooling and Machining Association, and other training providers. These activities are funded through a variety of sources including industry investment and state funding with ETIP, a unique resource for incumbent worker training used throughout the state. At a time where the skills needed in manufacturing have substantially increased, these investments are critical to the viability of the cluster.

State of Illinois Fiscal Problems Affect the Manufacturing Business Climate

Manufacturers want to invest in an environment they deem stable in the long term. Significant upfront costs in training workers, facilities and equipment mean manufacturers often pay back investments over the long term. The state's current fiscal uncertainty has stifled some appetite to invest in the region. The state's financial instability has impacted programs manufacturers rely on today. For example, decreased ETIP curtailed a critical source of support for industry's incumbent worker training.[184] The fiscal tumult has also impacted the state's overall business climate. For example, the increasing budgetary stress caused by unfunded pension obligations inhibits the State's ability to dedicate funding to transportation infrastructure, workforce development, and education. Restoring fiscal solvency would both convey stability for private investment and better position the State to make the investments needed to support the manufacturing cluster. Other current policies in Illinois compound the state's negative business climate. For example, worker compensation laws and unemployment insurance are higher than elsewhere in the Midwest and U.S., which puts Illinois at a competitive disadvantage.

[184] CMAP interviews with Valley Industrial Association and Chicago Jobs Council.

Standardized Industry Training and Certifications

Manufacturing was slow to develop and adopt an industry-wide skills training and certification system, but a comprehensive set of credentials is gaining traction among employers and training providers alike. Hiring in the cluster's core manufacturing entry-level production occupations is somewhat unique; historically employers could hire someone with mechanical aptitude and basic skills acquired in a high school shop class, for instance, and spend years training them on the job to be a machinist, welder, or mechanic.[185] Informal recruiting networks of family members and friends of current employees help the company fill openings by alerting friends or family to employment opportunities.[186] Employers use the training process to evaluate whether or not a worker was capable of properly operating the valuable factory machinery -- the cost of a worker damaging a machine can be extremely high, both in terms of repair or replacement and because of the productivity lost.

> ## Illinois Network for Advanced Manufacturing
>
> In the fall of 2012, a $12.9 million grant was made by the U.S. Department of Labor to the Illinois Network for Advanced Manufacturing, a consortium of 21 community colleges, to launch an Earn and Learn Advanced Manufacturing Career Lattice Program. The coalition is led by Harper College, which has seen success in current manufacturing programs and partnerships. Over the next three years, each participating college will partner with local manufactures and tailor their program to local needs. The funding will be used to create affordable training programs, develop staff and educational resources and provide access to free, digital learning materials. All materials developed will be available for use by the public and other education providers through a Creative Commons license.

Historically, production workers could reasonably expect to remain employed in the same industry, or even the same firm, for the majority of their career.[187] Factories invested in training workers with an implicit expectation that workers would stay at that factory for a long period of time and the employer's investment in building their skills would merit the expense.[188] In contrast, today's workers are encouraged to enter with formal training and experience because many of the region's small firms do not have the capacity to take on training new workers. The shift towards hiring workers already equipped with production skills may also be due in part to the fact that robots, automation, and other machines have replaced workers in jobs where they could take the time to observe the process and incrementally train to operate a machine.

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[185] Center for Regional Economic Competiveness, "U.S. Manufacturing Jobs: Where Companies Are Hiring," November 2011, pg. 13-14.

[186] CMAP interview with the Chicago Cook Workforce Partnership

[187] CMAP interview with the Chicago Cook Workforce Partnership

[188] Ray Prendergast, "America's Manufacturing Boom Could Be a Bust Without Right Education," Huffington Post, 8/22/2012.

As described in the previous section, shortages are mounting among production workers. A recent national effort led by the National Manufacturers' Institute (NMI) seeks to establish and train production workers on industry-recognized, nationally portable credentials. Even the lowest-skilled jobs require some detailed technical knowledge, understanding of the machines on the factory floor, and an awareness of safety standards. This national effort has created a set of production-related credentials, with aligned curriculum and standardized testing and has been endorsed by NAM, along with state partners like the Illinois Manufacturers' Association (IMA).

Manufacturers no longer have the resources to teach the skills on the job -- which is how many factory workers in the past built up their qualifications. The good news is that people who are interested in this field can enter by making a relatively small investment in their education. – Ray Prendergast, Manufacturing Technology Chair of Daley College[189]

While manufacturing training programs are not new, the nationwide certification system will allow employers, industry trade groups, policy makers, and training providers to quantify their effectiveness and more easily survey whether programs are meeting cluster demands. It also allows workers to incrementally acquire credentials, which provides flexibility and greater accessibility. The NMI Skills Certification System of Stackable Credentials is comprised of three levels -- an American College Testing (ACT) test to measure basic skills, the building and verification of production capacities, and more specialized components of manufacturing from metal forming to welding to engineering. School districts around the state, including Elgin, have begun to administer the test to students. Among the production capabilities, certificates can be related and cumulative, with clear progression in skills that branch out and become more specialized.

[189] Ray Prendergast, "America's Manufacturing Boom Could Be a Bust Without Right Education," Huffington Post, 8/22/2012.

Production and logistics technicians-specific credentials were developed by the industry-led Manufacturing Skills Standard Council. Both come with a standardized set of credentials corresponding to curriculum. Standardized tests are administered to verify the students' knowledge. The Certified Production Technician credential includes courses and assessments on safety, quality practices and measurement, manufacturing processes and production, and maintenance awareness.[192] The courses exemplify the complexity of work on a factory floor. The material is accessible to incumbent and prospective workers because much of the learning can be done through internet accessible programs where students can perform a wide variety of tasks, from reviewing safety procedures, to completing an electrical circuit.[193] Logistics technician's courses cover supply chain basics, materials handling, packaging, evaluation of transportation modes, and other building blocks of logistics.[194] Some area companies have even paid for training and provided incentives for incumbent workers to upgrade their skills through the program.[195]

Elgin Area Collaboration Around Manufacturing

The Elgin area has developed a robust partnership around improving worker skills. The collaboration is led by the Elgin Community College, the Elgin Area Chamber, and Elgin Unified School District #46 and engages stakeholders across the industry, several governmental entities, foundations, nonprofits, and other entities including Pace suburban bus service. The partnership has developed into a tight network in which manufacturers are talking with educators about how their workforce is performing and what gaps need to be filled.

One of the group's key efforts is towards ensuring that every Elgin High School graduate earns an ACT National Career Readiness Certificate (NCRC).[190] At the base level, the NCRC tests measure workplace competencies, similar to how the college prep ACT measures academic aptitude.[191] The NCRC work keys test information synthesis; problem solving; critical thinking; reading and using written, work-related text; applying mathematical reasoning to work-related problems; setting up and performing work-related mathematical calculating; locating, synthesizing, and applying information that is presented graphically; and comparing, summarizing, and analyzing information presented in graphical form. This partnership is an exemplar in the region -- demonstrating a best practice where industry leaders are knowledgeable and influential in driving the training programs and engaged in curriculum development while ensuring that what students are learning will be applicable in the workplace.

[191] Conference proceedings, "Manufacturers' Symposium," hosted by Elgin Community College and the Elgin Development Group, October 25, 2012.

[191] Conference proceedings, "Manufacturers' Symposium," hosted by Elgin Community College and the Elgin Development Group, October 25, 2012.

[192] National Association of Manufacturers, "About Stackable Credentials," 2012.

[193] "CPT Courses," Manufacturing Skill Standards Council, 2012.

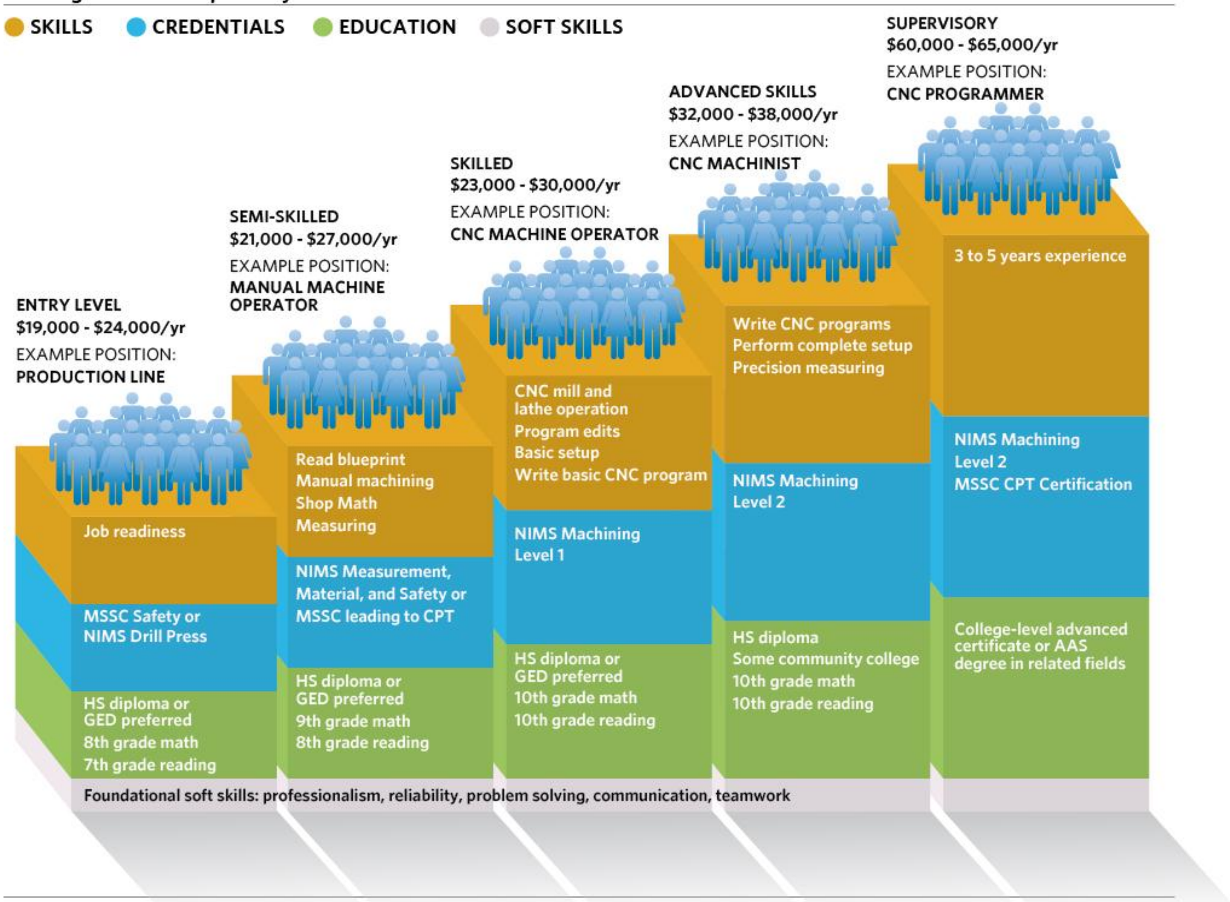
[194] "CLT Courses," Manufacturing Skill Standards Council, 2012.

[195] Conference proceedings, "Manufacturers' Symposium," hosted by Elgin Community College and the Elgin Development Group, October 25, 2012.

Using Stackable Credentials in Calumet

The Calumet region, which includes Chicago's South Side and southern Cook County, is a highly industrial area with connectivity to many of the region's transportation assets: water, rail, and highway. The Calumet Green Manufacturing Partnership has engaged training partners including Daley College, Prairie State College, and South Suburban College to train unemployed, dislocated, and incumbent workers using Manufacturing Skill Standards Council (MSSC) and National Institute of Metalworking Skills (NIMS) stackable credentials.[196] The trainees are recruited, screened, and matched to employers by a local nonprofit training and businesses service organization, OAI, Inc. The following chart is used by OAI to identify the skills, credentials, and educational milestones for prospective and experienced workers as they gain professional experience and complete coursework to advance their career in that area of the region.

Building block career pathway for CNC machinist



Source: CMAP analysis, 2012.

Local employers and municipalities, through the South Suburban Mayors and Managers, are closely engaged in the project. The Calumet Green Manufacturing Partnership leverages state and federal workforce training funds to improve skills of incumbent workers and train new workers with basic skills to advanced certificate courses that can lead to Associates degree programs. The stackable credentials are a key tool in this effort to spur economic development in the Calumet region, enabling employers, trainers, and local officials to develop cohesive strategies for preparing workers and equipping employers with the talent they need.

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Beyond the entry-level, skilled trades have also rolled out certification programs and curriculums. NIMS has established machining and metal forming certifications.[197] The modules are broken into several specific skills and relevant competencies a wide variety of manufacturers. The machinists and metalworkers can build their skills over a number of years, stacking the credentials as they pursue higher levels of education and employment.

Two other manufacturing-related trade associations have developed certifications. The American Welding Society has a Certified Robotic Arc Welding Program, a Certified Welder Program, and a Certified Welding Engineer Program that test a workers ability to work with structural steel, petroleum pipelines, sheet metal, and chemical refining industries on their own, with robots, or as an engineer. The Society of Manufacturing Engineers has developed two certifications; the technician's certificate may be acquired through undergraduate level programs of study in manufacturing or engineering or a combination of for years of academic work experience. An additional eight years of experience can be applied towards an engineer's certificate.

The credentials could play a role growing the region's manufacturing workforce. First, they set a generally accepted bar for local training providers, from remedial and bridge programs to specialized courses. At the same time, because employers no longer have the capability to train workers on their own, they can collaborate with training providers in the region that meet their needs. Finally, in an era where workers no longer expect to work for the same company their entire career, credentials provide workers with a way of signaling their level of skill and experience to the next employer. The credentialing system may just be the beginning of an overhaul how the manufacturing production workforce is trained.

One key hurdle remains for these standardized programs: Employers must widely adopt the credentials for the new system to be sustainable. Even workers who do have training can often find themselves starting on tasks that are beneath their level of expertise.[198] Unlike large employers, any small and even medium-sized manufacturers lack the staff time to study and use the credentials in their hiring process.[199] These credentials are not a panacea. The regional workforce system needs to stay abreast of credentialing to evaluate industry penetration, ensure they adequately train for the current workforce needs, and that they do not create an additional barrier to job seekers.

Role of Community Colleges

Metropolitan Chicago's community colleges, workforce development organizations, and high schools are also working to address workforce challenges, including identifying the pressing needs among employers in their service area and incorporating the relevant credential bearing courses into their system. In particular, community colleges around the region have already

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197 "National Institute of Metalworking Skills Credentials," National Institute of Metalworking Skills, August 2011.

198 CMAP interview, Elgin Community College.

199 CMAP interview, Chicago Cook Workforce Partnership.

begun developing programs to meet the needs of this changing workforce. The City Colleges of Chicago are undergoing a transformation to gear the schools towards preparing students for careers, redeveloping remedial classes and offering course that fall along a developmental scale. Daley College on the City's south side is now responsible for manufacturing training and working with employers ensure that training remain relevant and students have opportunities to successfully enter the cluster. Suburban community colleges have also led the way in finding more efficient ways to exchange knowledge and maximize their resources. All of these developments demonstrate steps to improve the services they are offering. Training for manufacturing can be prohibitively expensive because of the costly equipment and limited pool of instructors. GO TO 2040 underscores the importance and benefits of effective, collaborative approaches towards addressing common challenges, like the region's skills gap. Manufacturing is a regional activity and increased coordination among the numerous partners, industry, trade associations, and other training providers has the potential to reap long-term benefits for both employers and students.

On-the-Job and Apprenticeship Training

Manufacturing is particularly conducive to training on-the-job and apprenticeships because employers need to show workers their unique processes and machinery. While doing this, they can evaluate whether the worker has promising characteristics to learn and grow and if the worker is skilled enough to be trusted around machinery that can cost hundreds of thousands or millions of dollars. Manufacturers throughout the region are working in partnership with trainers and educators to develop apprenticeships.[203] One model some companies look to is the U.S.-adapted Volkswagen apprenticeship in its Chattanooga plant. A variety of national and international models are available for study. Each approach includes very close collaboration between educators and industry. The Danish system is grounded in continual workforce training and re-training of workers, and regional stakeholders including employers, trade unions, social welfare organizations, and training providers closely monitor the quality of the

German Style Apprenticeships in Chattanooga's VW Plant

German manufacturers train their workforce through a rigorous industry-wide system of vocational schools and apprenticeships. While the German system relies on a pipeline of vocational school students not slated to go to college, a small group of employers is working to bring a form of the apprenticeship model into American manufacturing.[200] Volkswagen's Chattanooga plant has worked with area community colleges to train the skilled workers it needs to maintain its factories' high-tech robotics and assembly line systems.[201] The apprentices are trained through a partnership with the Chattanooga State Community College. Students are screened and tested in math and reading skills, and to enter the program Volkswagen administers a test in which applicants read diagrams, assemble car parts, and install a dashboard. The first group of recruits is expected to graduate in 2013 with jobs guaranteed at Volkswagen.[202]

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200 Dana Goldstein, "The Apprentice: How Manufacturers and Community Colleges are Teaming Up, German-Style, to Create High-Paying Factory Jobs," Slate, September 12, 2012.

201 Vanessa Fuhrmans, "Germany's New Export: Jobs Training," Wall Street Journal, June 14, 2012.

202 Dana Goldstein, Slate.

203 CMAP interview with Daley College Manufacturing Program.

curriculum and outcomes for employees and employers.[204] An Australian system moved from academic to competency standards, and created industry-wide career ladders.[205]

Starting in 2012, opportunities became available for military veterans to translate their on-the-job training and armed forces-specific training into civilian certifications.[206] All of the credentialing and licensing organization mentioned previously, NCRC, MSSC, AWS, NIMS, and others like the Society of Manufacturing Engineers, are participating on a task force to identify which military specialties are readily transfer to high-demand jobs; work with civilian credentialing and licensing associations to address gaps between military training programs and credentialing and licensing requirements; and provide service members with greater access to necessary certification and licensing exams.[207] The Department of Defense estimated that the program would provide opportunities for over 125,000 service members to gain industry-wide, nationally portable certifications in manufacturing jobs.[208]

A Manufacturing Careers Internship Program (MCIP)

Focused in Northern Cook County, the MCIP is a Workforce Investment Act (WIA) youth program that serves to connect young adults to the career opportunities in the manufacturing industry by offering internships. Launched in 2011, year, the program has already seen notable results, including 71% of the MCIP interns are offered manufacturing jobs or are pursuing advanced education and 55% of the MCIP interns get jobs at the site of the internship.

Science, Technology, Engineering, and Mathematics Education

An underlying factor in many of the cluster's workforce challenges is a dearth of workers with strong skills in science, technology, engineering, and mathematics (STEM). For example, over the past five years, graduates in IT have decreased.[209] Addressing this challenge would not only strengthen several industries in the manufacturing cluster, it would also strengthen other fields like health and computer and information sciences. For the region to keep pace with demand for scientific or IT training, students need preparation in these fields of study. Without a strong supply of computer and natural scientists the cluster will be challenged to create and implement new technologies, like those explored in the innovation section of this report, or operationalize the new processes and tech-based equipment discussed through the report.

[204] "Closing the Gap, Surpassing the Competition: City Colleges of Chicago, Manufacturing, and International Best Practice," Chicago Manufacturing Renaissance Council, November 31, 2006.

[205] Ibid.

[206] Claudette Roulo, "Obama Announces Military-to-Civilian Skills Certification Program," American Forces Press Service, Department of Defense, June 1, 2012.

[207] "President Obama Calls on Congress to Act on Veterans Job Corps in "To Do List" and Launches New Military Credentialing Initiative to Fill Workforce Needs," Office of the Press Secretary, The White House, May 31, 2012.

[208] "President Obama Calls on Congress to Act on Veterans Job Corps in "To Do List" and Launches New Military Credentialing Initiative to Fill Workforce Needs," Office of the Press Secretary, The White House, May 31, 2012.

[209] Integrated Postsecondary Education Data System, "Digest of Education Statistics: 2011," National Center for Education Statistics, US Department of Education, 2011.

Building off of the U.S. Department of Education's Race to the Top initiative, emphasizing STEM curriculum, the Illinois Department of Commerce and Economic Opportunity is leading the Illinois Pathways STEM programs of study, which links students from pre-school through college to career paths with the objective of preparing students for careers in a variety of important industries, and ultimately spurring economic growth.[210] The Pathways expose students to a wide variety of careers and relate education, training, and experience needed to explore any of the nine distinct pathways ranging from agriculture, to finance, to manufacturing.[211] Corresponding "learning exchanges" where industry leaders, educators, relevant nonprofit groups, local and state government representatives are a forum for industry and educators and training providers to support the related program of study.

At the national, state, and regional level, educators are raising the standards for student achievement in science, mathematics, and literacy -- all core competencies in the cluster. Illinois Pathways are one of the core strategies that the state is pursuing to raise the bar for students in the region. The Pathways focus on building career awareness and as students get closer to the workforce, they can build skills toward a particular occupation or industry.

Advanced manufacturing is really complicated. Running these machines requires a basic understanding of metallurgy, physics, chemistry, pneumatics, electrical wiring and computer code. It also requires a worker with the ability to figure out what's going on when the machine isn't working properly. – Adam Davidson, New York Times

[210] Brooke Anderson, "Governor Quinn Launches New Education Initiative to Support Economic Growth," Illinois Department of Commerce and Economic Opportunity, February 9, 2012.

[211] Jason Tyszko, Illinois Department of Commerce and Economic Opportunity, Presentation to CMAP Economic Development Committee, April 24, 2012.

Figure 37. Manufacturing Training Pathways From Middle School to Postsecondary

Orientation (e.g. Middle & High School)	Pathways (e.g. High School)	Postsecondary Education and Training Bridge / Certificates and Associates / Bachelors / Graduate	Careers
Technology Orientation Co Wo Cr	Manufacturing Production Process Development Co Wo Cr Pa	Manufacturing Production Process Development Co Wo Cr	Careers
	Production Co Wo Cr	Production Co Wo Cr	Careers
	Automation Co Wo Cr Pa	Maintenance, Installation and Repair Co Wo Cr	Careers
	Logistics and Inventory Control Co Wo Cr Pa	Logistics and Inventory Control Co Wo Cr	Careers
		Quality Control Co Wo Cr	
		Health, Safety, and Environmental Assurance Co Wo Cr	

Co = Courses Wo = Work-Based Learning Cr = Credentials / Assessments
Pa = Shared Pathways

Source: Illinois Pathways Initiative, IllinoisWorkNet.com.

Many low- and mid-skilled jobs in the cluster have been replaced by technology.[212] As discussed in previous sections of this report, in the past ten years, Chicago's manufacturing workforce has shrunk by over one-third, but productivity and output have steadily increased. Each worker on a factory floor is expected to know and do more than ever before.

High-Road Manufacturing: Working As Team

Innovative processes require workers that are problem solvers, take initiative, and communicate well. Labor-intensive production that requires minimal skills is not likely to return to American shores. However, where innovation or efficiencies can improve a product, American manufacturers still have a distinct advantage.[213] One important avenue for assuring continual improvement in manufacturing is known as high-road manufacturing. The term refers to full involvement of workers across the production and process spectrum. GE has pursued this model with a high degree of success in its once nearly defunct Appliance Park -- spurring a $1 billion investment to expand manufacturing where teams ranging from scientists to machinists are tasked with producing refrigerators or dishwashers more efficiently or further improving a product.[214] This level of collaboration is only possible where everyone on the team is equipped with relevant expertise.

One local effort is taking a much more direct approach than the Illinois Pathways initiative to prepare a manufacturing workforce. Founded with the leadership of the Chicago Renaissance Council in 2007, Austin Polytechnic Academy (APA) on Chicago's west side is a magnet high school preparing students with the skills needed in advanced manufacturing. Students work

212 Adam Davidson, "Making It in America," *The Atlantic*, January/February 2012.

213 Deloitte Touche Tohmatsu, "The Challenge of Complexity in Global Manufacturing," 2003.

214 Jeffery Immelt, "GE CEO on Sparking an American Manufacturing Renewal," Harvard Business Review, March 2012.

through rigorous curriculum but, unlike most schools, they are able to translate abstract concepts, like problems in calculus, into functional objects. Students and teachers also visit factories to see first-hand how factories make their products. In the classroom, the fundamental ingredients of a modern factory floor, including STEM, are much more tangible.

APA students prepare for work in advanced manufacturing and many other careers that will survive in a more automated world, where extensive mathematical reasoning, literacy, and the ability to communicate professionally with other people are paramount. APA students benefit from the school's many industry partnerships learning about production, engineering, management, even ownership. APA students enter a variety of occupations from CNC machining with some post-secondary training to engineering with a college degree. The school is located in a largely economically depressed neighborhood, but it has close proximity to the Pulaski Industrial Corridor. Although the program is still small, around 200 students, APA is now a national exemplar, and the program continues to grow -- the City of Chicago invested $1.25 million dollars in the school to expand its programming to include career support services and adult education.

Workforce Opportunity: Planning for an Advanced Manufacturing

Workforce and economic development decisions are closely related topics for municipalities. On a routine basis, communities make decisions based on the potential economic benefit for a community, such as jobs and tax revenues. While the next section of the report will examine the manufacturing cluster's infrastructure needs, it is important to acknowledge that workforce training and economic development planning do not happen in a vacuum. CMAP's GO TO 2040 plan connects traditional planning issues, such as land use, resource management, and mobility, with workforce development and pursuing coordinated investments to increase efficiency and efficacy at every level of government. School districts, community colleges, community-based organizations, and local governments work together routinely to understand how to more adequately prepare the workforce. At the same time, communities also put considerable energy into supporting local businesses and planning land use. The connection between those seemingly disparate arenas is rarely made, but as policy makers and local officials focus on improving workforce training, they can link the decisions.

Next Steps to Train the Advanced Manufacturing Workforce

Strengthen and scale-up coordination between industry, educators, and training providers to match skills development with industry needs.

Coordination among the region's training providers, educational institutions, and the private sector is necessary to upgrade the skills of the cluster's production workforce. Coordination will help leverage the resources required for the costly training programs; students need access to the latest equipment and ongoing training to develop and adapt their skills to technological advances. Coordination will also ensure that training programs adapt to changes in skill-needs. As the manufacturing workforce is increasingly a state and federal priority, new competitive grant opportunities are helping facilitate the coordination between the many stakeholders involved in training and policy and the region needs to better position itself to seize these opportunities.

The region's challenges are unique in part because of the diversity of industries and the scale of the cluster. Therefore, it requires significant resources to establish and support sustainable partnerships. Public/private coalitions can help provide an organizing framework to identify large-scale challenges, attract funding, and address policy barriers. Coalitions could take on a variety of activities including applying for and administering grant programs, realigning workforce training opportunities where appropriate, ongoing recruitment and career awareness building, and developing strategies to address acute and long-term production workforce needs. Several models have emerged in the recent past, like the Calumet Green Manufacturing Zone and Illinois Network for Advanced Manufacturing.

Increase STEM attainment and prepare students for high growth occupations.

Many end products of the manufacturing cluster -- manufactured goods and logistics for example -- permeate everyone's daily lives, however students are often unaware of the innovation and ingenuity that created them. This is a challenge for the region because advanced manufacturing requires an adequate supply of scientists, engineers, and technologists. To build a sufficient pipeline meeting the demand of advanced manufacturing, students at the middle and high school levels need to be more inspired to pursue study in STEM subjects.

Stronger connections between middle and high school educators and the region's industries will provide experiences to real-world applications of STEM which in turn will lead to greater STEM attainment. Exposure to a variety of innovative and growing occupations can encourage students to pursue further study and seek out apprenticeships and internships in fields like manufacturing and tech-based logistics. STEM subjects can be daunting for students, but these opportunities can show students how coursework in computer programming, trigonometry, or chemistry relates to advanced manufacturing, which uses cutting edge technology for making innovative products. Building a sustainable and productive exchange between industry and educators will require long-term investment but are needed to avoid acute workforce shortages as advanced manufacturing grows.

The Illinois Pathways and its STEM Learning Exchanges is a recent state-wide effort aiming to encourage more STEM learning and ensure curriculum is aligned to current and emerging jobs and skill needs. This initiative works to help dispel misconceptions about careers in manufacturing and inform students and educators about the opportunities among higher-skilled jobs in the cluster.

Improve pathways into jobs and apprenticeships to build trust between employers and lower skilled workers.

Basic workforce preparation programs that teach basic skills such as math and reading comprehension in the context of a specific occupation provide essential preparation and improve transition from training to jobs for many low-skilled workers. These types of contextually based training programs are an effective way to develop pathways and soft-skills needed by lower skilled workers. To work on a factory floor, workers need to be able to follow safety protocols, use caution in dealing with machines, and execute tasks precisely to keep production moving. However, some current training programs for lower skilled workers are not meeting industry needs because of attrition. Workers that do complete training could also benefit for a more immediate and clear path to employment.

Community-based organizations, workforce investment boards, community colleges, and other training programs that conduct and deliver workforce programs need to develop and deliver workforce training in ways that meets the skill needs of the advanced manufacturers, as well improves access to lower skilled workers. This could be done through a variety of innovative solutions, including bridge programs, on-the-job training, and apprenticeships. Currently, promising students move from beginner level training programs to advanced training, but could benefit from manufacturing work experience components. Steps should be taken to explore new models that equip students with a secure job as they determine which of the many specializations available would fit well with their skills.

Plan for the workforce on subregional and local levels to tailor services towards local industries, institutions, and workers.

The cluster's workforce challenges are diverse and widespread, requiring longer term and more local planning. No single policy or initiative can adequately address the needs of the region's diverse manufacturing industries. Instead, localized or subregional solutions tailored towards area industries, institutions, and workers can enable stakeholders to implement appropriate and achievable strategies. For example, related industries in the region tend to co-locate in close geographic proximity and could benefit from working with one another to develop solutions to shared problems. Many manufacturers and small training providers do not have adequate resources to train their workers, and by working together in subregional partnerships, area resources for training could be used more efficiently. Existing and emerging initiatives can serve as best-practices that can be leveraged and expanded.

Municipalities and subregions benefit from long-range planning to support economic innovation and improve education and workforce development strategies that are tailored towards the unique needs of their communities. CMAP's Local Technical Assistance (LTA) program provides a strong model for nonprofits, municipalities, counties, and interjurisdictional groups that have identified challenges and worked cooperatively to develop and implement plans that address shared resources. For example, in both Hoffman Estates and Morton Grove, LTA projects are examining those municipalities manufacturing assets and how the communities' could harness those assets for further growth.

Infrastructure

In addition to innovation and workforce, the region's infrastructure will impact the future of the cluster. To bolster the competitiveness of the regional manufacturing cluster, metropolitan Chicago will need to make strategic investments in its infrastructure. As the chairman and CEO of General Electric -- one of the world's largest manufacturers -- recounts, manufacturing infrastructure means much more than just transportation assets: to stay competitive, "We'll need an updated infrastructure to support manufacturing, which the private sector can help fund -- better roads and airports, broadband capability, and a bigger and smarter electricity grid."[215] This chapter addresses the key infrastructure themes that influence manufacturing competitiveness, including transportation, energy, and physical infrastructure, highlighting challenges and opportunities for lasting regional cluster growth.

Transportation Infrastructure

From primary materials to intermediate parts to final products, manufactured goods are constantly on the move through supply chains that span regions, continents, and even the globe. In today's mobile economy, production is not restricted to where a resource was extracted; likewise, final consumption generally takes place far from the factory floor. To a degree likely unmatched by any other segment of the economy, manufacturing relies on transportation infrastructure to both receive inputs necessary for production and also ship finished goods to market. As such, an efficient and reliable transportation infrastructure is an essential component of any successful manufacturing cluster. This section opens with how transportation infrastructure supports regional supply chains and exporting, and then turns to current challenges and opportunities facing the regional transportation system.

Transportation Infrastructure and Regional Supply Chains

At Henry Ford's massive River Rouge plant, raw materials were transformed into running vehicles under a single roof. This model epitomized American mass manufacturing in the 20th Century. While many manufacturers continue to use this model to stay competitive, others have come to focus just on core competencies. The result of this specialization has been the outsourcing of key supply chain functions so that many OEMs may manufacture very little and instead assemble a final good out of numerous intermediate parts developed elsewhere. The dispersion of supply chains is especially important in advanced manufacturing firms that tend to operate in a specialized niche market.

> Even in a globalized world many manufacturing supply chains remain regional, as half of all manufactured goods move less 50 miles. Advanced manufacturers in particular rely on regional transportation infrastructure for connections to niche suppliers and final equipment producers.

[215] Jeffrey R. Immelt, "How We Did It…The CEO of General Electric on Sparking an American Manufacturing Renewal," Harvard Business Review, March 2012.

As less content of a final good is manufactured at a single facility, transportation infrastructure becomes more important for complex supply chains. Product supply chains stretch across the nation and globe, but as chapter 1 of this report noted, half of all manufactured goods movements in the U.S. are still less than 50 miles. Behind the final product exported by a regional firm are a combination of smaller moves of intermediate parts that often take place within a metropolitan region or day's truck drive. As such, a competitive manufacturing cluster must have sufficient intra-regional transportation infrastructure.

For metropolitan Chicago's manufacturing cluster this intra-regional transportation is particularly important in industries with low value-to-weight ratios, such as primary metals, as well as those geared towards local consumption like food and beverage manufacturing. Census data document how these industries have a greater proportion of total moves that take place within metropolitan regions.[216] Intra-regional transportation infrastructure is also vital for advanced manufacturing industries where the region has developed supply chains, such as machinery. Unlike machinery firms in other regions that tend to utilize longer supply chains, advanced machinery in metropolitan Chicago has a developed regional supply chain that builds off concentrations in primary and fabricated metals.[217] As one manufacturer put it, the region is the "machine tool hub of the world." The concentration of machining and metalworking firms in the region means that almost any tool or part can be met "by a firm right down the street."[218]

Transportation Infrastructure and Exporting

Metropolitan Chicago exports more manufactured goods than any domestic region except Los Angeles.

In addition to enabling supply chain moves within the region, metropolitan Chicago's transportation infrastructure also connects local firms to domestic and global markets through exports. Exports fuel economic growth by increasing market exposure and introducing new dollars that otherwise wouldn't be captured in the regional economy. While the Chicago tri-state[219] region is the nation's third largest exporter for all products (raw materials, manufactured goods, and services) it is the second largest exporter when looking only at manufactured goods. In 2010, firms in the tri-state area exported abroad manufactured goods valued at over $34 billion. This made up 63 percent of the region's total export portfolio, a higher rate than both Los Angeles and New York, the nation's other top exporting regions.[220]

Transportation Infrastructure Opportunities

Metropolitan Chicago boasts a superior transportation network that grants the region a competitive edge in the global economy and has long been an asset for regional manufacturers. Metropolitan Chicago is the only domestic region served by six of the seven Class I (i.e., major)

[216] CMAP Analysis of U.S. Census Commodity Flow Survey for year 2007

[217] CMAP Analysis of U.S. Census Commodity Flow and EMSI multipliers.

[218] CMAP interview with Kay Manufacturing Co.

[219] Export data are captured at the MSA level. As such, this section uses data for the Chicago tri-state region.

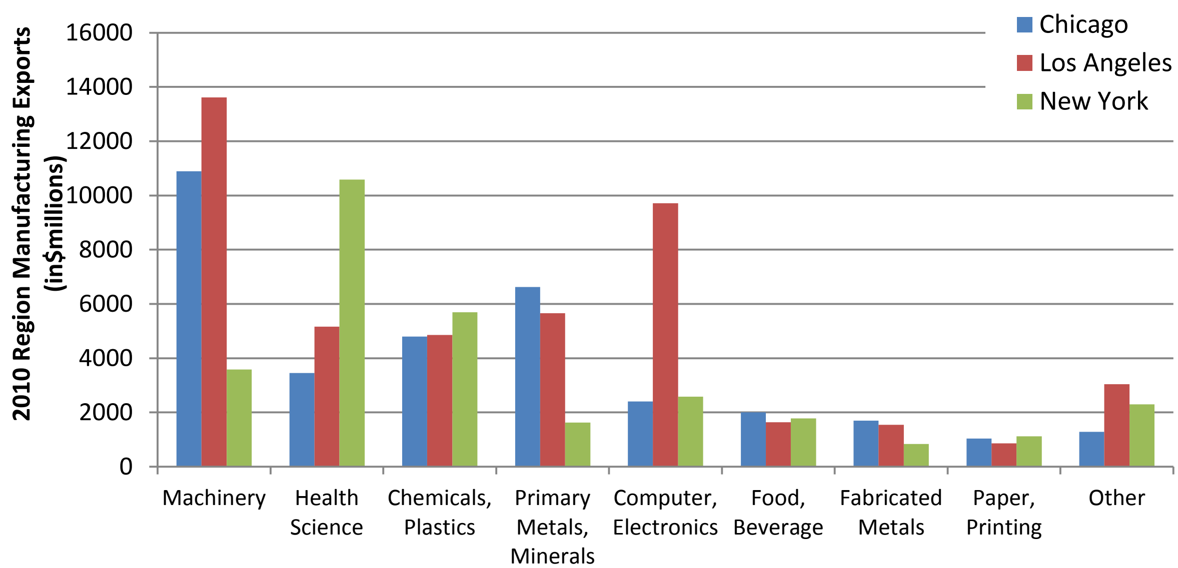
[220] CMAP analysis of Brookings "Export Nation 2012"

railroads, boasts seven interstate highways in the region, and has the nation's second busiest airport in terms of international air cargo.[221] This existing transportation infrastructure grants superior access to both domestic and foreign markets. The region's broad collection of manufacturing industries and impressive exporting numbers are a reflection of this extensive transportation system.

Exports an Area of Growth for Regional Advanced Manufacturing Firms

As 95 percent of consumers live outside of the U.S., exporting holds vast growth potential for regional firms. Exports in the Chicago region are led by advanced manufacturing in machinery products whose $11 billion worth of exports in 2010 were an impressive 50 percent higher than inflation-adjusted 2003 levels. Advanced chemicals, health sciences, and computer/electronics also are important exporting industries, as well as primary metal and petroleum firms that target strong demand in developing countries. To reach these distant markets and the ever-growing global consuming class, regional manufacturers rely on metropolitan Chicago's transportation infrastructure-- seven interstate highways, six major rail carriers, numerous intermodal terminals, and the nation's second busiest airport for international cargo.

Figure 4. Exports from Nation's Three Largest Regions



Source: CMAP analysis of Brookings' "Export Nation," 2012 for Chicago tri-state region.

A recent survey of 1,000 industrial businesses in the region found that close to two-thirds picked Chicago's air, truck, rail, and intermodal capabilities as the primary reason they operate in the region.[222] Regional manufacturers confirmed the importance of this freight/manufacturing connection when speaking to CMAP. Firms related how expedient it is to get necessary inputs using the region's intermodal rail and truck system. This same system grants access to move goods to distant markets, and the region's airports can be used if operating under heightened

[221] CMAP Freight Drill-Down, p.3.

[222] Center for Neighborhood Technology. "Prospering in Place," February 2012, p.22.

time pressure. Most noted that metropolitan Chicago was an ideal transportation location: "It is easy to get to anywhere on the national level." Regional manufacturers also expressed that transportation access was a key locational decision when expanding operations.

Transportation Infrastructure Challenges

Congestion threatens to undermine the transportation advantages currently enjoyed by manufacturers in the Chicago region. Already the region is among the most congested in the nation, costing firms billions of dollars a year in lost time and fuel.[223] Even more than lost fuel and time, regional manufacturers may be most impacted by decreased shipment reliability, especially for those firms operating under just-in-time models. Projected increases in both population and freight traffic will only exacerbate these issues.

While the Chicago region is not alone in facing serious challenges around its transportation infrastructure, its status as the nation's freight hub mean these issues are more pronounced. Like other parts of the country, the region is finding it more difficult to finance infrastructure improvements because of the decreasing purchasing power of federal and state motor fuel tax receipts among other issues. In short, the methods and sources for financing transportation infrastructure are not keeping pace with the demand for maintenance, modernization, and expansion. CMAP's Freight Cluster Drill-Down and the Regional Mobility chapter of GO TO 2040 describe in depth the regional challenges around transportation infrastructure as well as targeted strategies moving forward.[224] These strategies to preserve our region's status as the nation's transportation infrastructure hub include prioritized investments, innovative financing, and improved freight governance. First, the region needs to invest strategically in major capital projects that have the greatest benefits for regional mobility and accessibility. For example, the Elgin-O'Hare Western Access would improve throughput and reliability on corridors serving a major node of the manufacturing cluster. Communities in this project's area contain some of the region's largest concentrations in both freight and manufacturing employment. Second, innovative financing through measures such as congestion pricing can support the region's prioritized investments. Congestion pricing not only builds a regional source of revenue, but also helps manage traffic

Public-Private Partnership Supports Rail Infrastructure Investment

Local manufacturing firms rely on the region's rail networks to bring in bulk inputs as well as export finished products to distant markets. As the only domestic region served by six of the seven major railroads Metropolitan Chicago moves an astonishing half of the nation's rail freight, yet this concentration leads to congestion and delays. Recognizing that freight rail supports not only the manufacturing cluster but the overall economy as a whole, a group of public and private partners including the U.S. Department of Transportation, the State of Illinois, the City of Chicago, Metra, Amtrak, and the nation's freight railroads formed the Chicago Region Environmental and Transportation Efficiency Program (CREATE) to prioritize and fund rail infrastructure projects. CREATE showcases the level of collaboration often seen in clusters, drawing on the region's freight institutions to address a serious infrastructure congestion challenge.

[223] Metropolitan Planning Council, "Moving at the Speed of Congestion," 2008, p.5.

[224] CMAP's Freight Cluster Drill-Down available at http://www.cmap.illinois.gov/freight-drill-down. GO TO 2040's Regional Mobility chapter can be found at http://www.cmap.illinois.gov/2040/regional-mobility.

and gives drivers more choice. Finally, system coordination can be improved through freight governance to guide investments and reduce redundancies in the system.

Physical Infrastructure

In addition to transportation infrastructure, manufacturing firms rely on further physical infrastructure in their operations. Two especially important ones are land use and broadband capabilities.

Land Use

Regional land use patterns influence manufacturing activities in a number of ways. Decisions about where to site industrial development can connect industrial districts across the region or instead create pockets of isolated manufacturing activity. And as workers commonly live in one community and work in another, land use decisions affect how the manufacturing workforce gets to the factory floor. This section explores manufacturing land use challenges and opportunities in metropolitan Chicago, beginning with the difficulty of balancing industrial land with commercial and residential use.

Land Use Challenge: Loss of Industrial Land

With the highest economic multiplier of any economic activity, manufacturing provides significant benefits to the regional economy in terms of wages, jobs, and output. Yet after a decade of substantial job loss, many communities perceive the industry to be in decline. Compounding the issue, manufacturing land use generates no sales tax revenue to the individual municipality unless the final point of sale also coincides in the same location.

Many communities have numerous sites of vacant or underutilized industrial land, yet after use for a century or more this land often has been split into numerous smaller parcels with individual owners. This fragmentation of parcels makes underutilized land in existing communities less attractive for manufacturing purposes that require large footprints, leading many to propose redevelopment towards alternative uses that don't require land assembly. Years of industrial activity also means that existing underutilized industrial land could be environmentally contaminated; municipalities often look to remediate land back to a type of productive use that won't propagate environmental degradation.

Because of these varied factors many municipalities in the region have oriented land use planning towards other uses that generate fewer externalities and more revenue, like retail and single-family residential. Preserving manufacturing land for future industrial development represents a serious challenge -- without dedicated land use, the region's manufacturing future could face challenges.

Land Use Challenge: Tax Policy and Uneven Development in Cook County

Cook County's current tax policy presents its own formidable challenge for manufacturing land use, as it is the only county in the state that assesses commercial and industrial properties at a percentage of market value higher than residential properties' percentage. As a result, businesses in Cook shoulder more of the property tax burden than residents do (although the magnitude of this impact varies from place to place). This disproportionate burden does not exist in the collar counties, where businesses and residents with similar property values typically share similar tax burdens. The higher tax burden on businesses in Cook County creates a discontinuity in taxation within the region, creating an imbalance in regional industrial land development and impeding implementation of the GO TO 2040 recommendation for infill redevelopment to strengthen existing communities. Keeping the current system could be a recipe for low growth for Cook County's manufacturing base, in turn putting a greater tax burden on both residents and businesses.

Land Use Opportunity: Infill Development

While manufacturing employment loss this past decade has led to underutilized industrial land in communities across the region, often this same land is in areas serviced by superior transportation infrastructure. In addition to transportation, infill land also provides the water, sewer, and utility connections that can be a challenge for new development on the fringe of the region. In a 2008 study, CMAP estimated over 184,000 acres of underutilized land in the region poised for development, underscoring the region's potential for infill development.[225]

Targeting future manufacturing expansion towards the region's infill areas can leverage existing transportation assets and also better connect jobs to where people live. The same infill areas serviced by existing transportation infrastructure often lie in close proximity to an existing workforce familiar with manufacturing. In interviews with CMAP, regional manufacturers stressed how important it is to locate in areas accessible to their employees. Firms located near their manufacturing workforce praised the effect of a short commute for morale and productivity and recognized that good transportation connections could help attract those skilled elements of the labor force that might live farther away. The opportunity to use the region's substantial infill stock for development could offer these workforce advantages to new manufacturing investment.

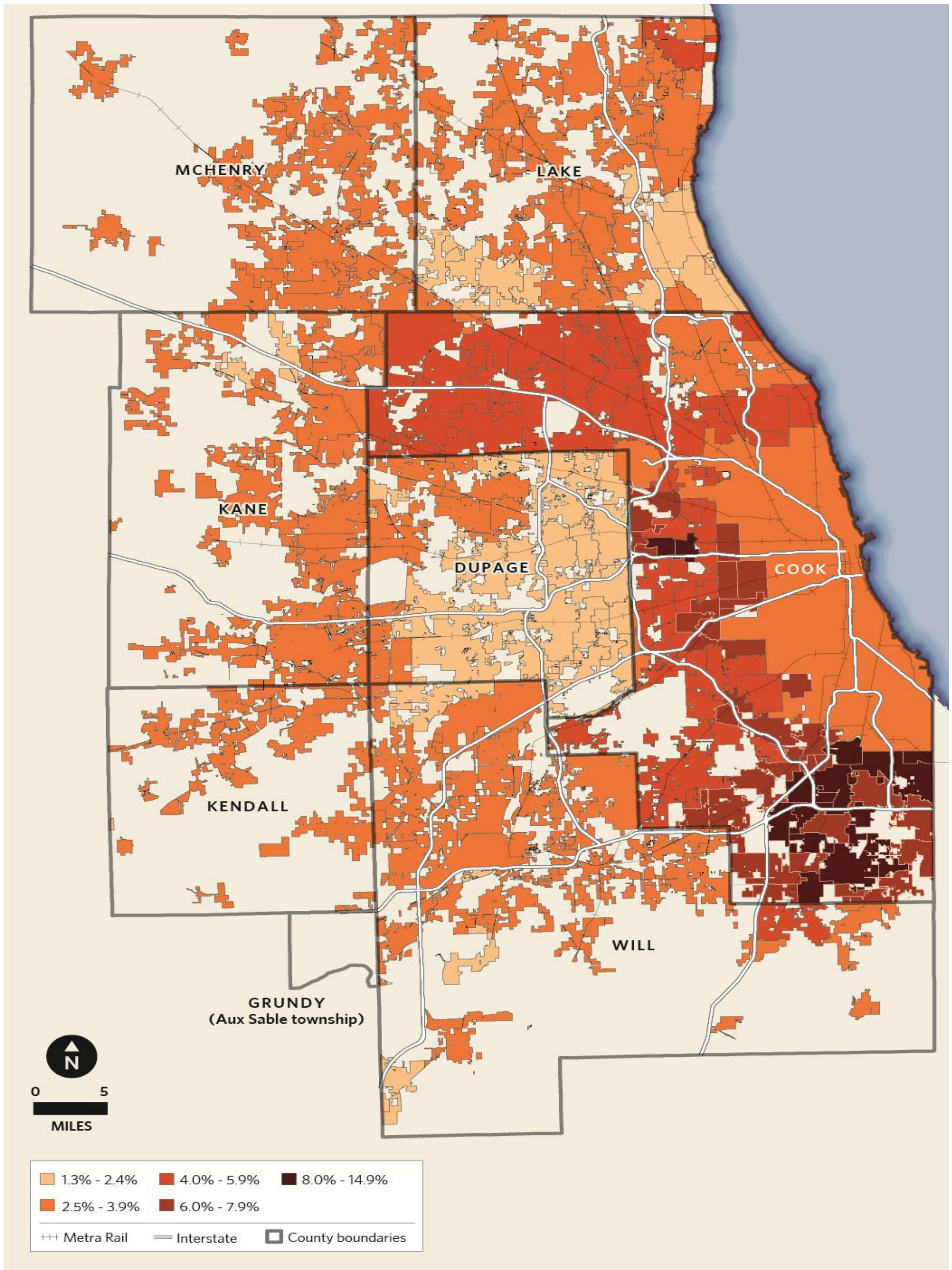
Finally, while land assembly will remain a challenge for some large scale manufacturing, many more projects will be small and medium-sized operations that can take advantage of the region's infill stock: 84 percent of manufacturing firms in the region employ less than 50 workers. And as manufacturing in the region continues to shift to hi-tech products and process, advanced manufacturing such as additive 3D printing or bio-manufacturing will produce little waste and pollution, reducing manufacturing's negative externalities. Many traditional manufacturing activities (such as smelting, refining, etc.) will continue to need separation from other land use, but some types of advanced manufacturing can be better integrated with other regional land use.

Industrial Land Protection Effort

The City of Chicago's Planned Manufacturing Districts preserve land in key industrial corridors from non-manufacturing uses that would displace or restrict industry growth. The 15 districts show a commitment on the City's part to support future manufacturing activities.

[225] CMAP, "Infill and Redevelopment Regional Snapshot," 2008.

Figure 5. Effective Composite Tax Rates for Industrial Property, 2009



Source: CMAP, 2012.

This map illustrates effective composite property tax rates levied for industrial property taxpayers by municipality in 2009. "Effective" means that the rates are expressed as a percent of the market value of properties, rather than the equalized assessed value of properties. The rates shown are also "composite," which means they include rates levied by counties, municipalities, school districts, and special districts. The rates levied by special service areas are excluded in this analysis. As shown, municipalities in Cook County -- especially in the south suburbs -- have the highest regional tax rates for industrial properties. This discontinuity in taxation creates an imbalance in regional industrial land development.

Land Use Opportunity: Local Technical Assistance Program

CMAP's LTA program provides assistance to communities across the Chicago metropolitan region to undertake planning projects at the intersection of transportation, land use, and other quality-of-life elements. One advantage of the program is that it helps situate local development issues within larger trends. For instance, after a decade of job loss many municipalities across the region have considered redeveloping manufacturing land into commercial or residential use. The LTA program can offer local municipalities a regional perspective on manufacturing land use, showing how the region's continued shift to advanced manufacturing presents opportunities for economic growth and how manufacturing within individual communities fits together in an interconnected regional cluster. This larger perspective helps municipalities make informed local land use decisions that capitalize on regional strengths and trends.

For example, a current LTA project in Morton Grove will help prepare a subarea plan for the Village's industrial areas. Situated in a manufacturing submarket that includes Skokie, Niles, and Lincolnwood, Morton Grove contains two industrial areas with diverse manufacturing output. The subarea plan will examine these industrial areas' relationship with surrounding land use as well as the regional industrial market. While employment in the industrial areas declined the past decade, work underway shows how they continue to be a major job center for the submarket. A regional outlook also shows how these local areas are well positioned to take advantage of a continued shift to advanced manufacturing. One particular attribute aiding the Village's transition to advanced manufacturing is a local workforce system tailored towards the cluster that can respond to changing workforce needs. While past manufacturing employment loss may lead some to suggest redeveloping industrial areas into other uses, work through the LTA program recommends preserving manufacturing in the village to match local assets with emerging regional developments.

Broadband Infrastructure

Factories are increasingly saturated with technology and as a result, manufacturers need faster and more reliable telecommunications networks. Manufacturers use broadband-enabled technologies for every aspect of their businesses from employee training, inventory tracking, ordering, customer relations, and R&D to managing and controlling machinery on the factory floor.

Broadband Challenges

Small manufacturers are challenged by inadequate access to the highest speed and capacity broadband. A basic threshold for being able to transmit data-rich information is 5 megabytes per second (mbps)[227] -- in Illinois, the median download speed for small businesses is 4.1 mbps;

"Manufacturers have become increasingly dependent on wireless Internet and advanced telecommunications devices in their daily operations to connect with customers, employees, suppliers and valued partners." Brian Raymond, National Association of Manufacturers[226]

[226] Raymond, Brian, Director of Technology Policy. *Letter to Committee on Energy and Commerce, US House of Representatives.* National Association of Manufacturers. February 13, 2012.

[227] Illinois Innovation Index, May 2012 edition.

for comparison, medium to large businesses median download speed is 10.1 mbps.[228] As the vast majority of manufacturing firms are small businesses, better broadband connectivity would strengthen the manufacturing cluster.

Broadband Opportunities

A number of local and state-level initiatives are underway to address this challenge. Broadband Illinois, a nonprofit funded with public and private monies, works to better understand the state's connectivity challenge and develop strategies to improve broadband infrastructure.[229] Other projects increase actual physical infrastructure. The Gigabit Communities challenge is laying 4,100 miles of new fiber optic cable throughout Illinois to connect over 5,000 communities to ultra-high-speed networks.[230]

The region boasts one of the world's most advanced broadband networks. A partnership of UIC, Northwestern University, Argonne National Laboratory, Canada, and the Netherlands, StarLight is an optical network that serves as the international hub for dozens of other research networks worldwide.[231] StarLight scientists currently are working to build on this asset by designing the world's first multi-100 gigabytes per second (gbps) exchange.

Though local, state, and the federal government are increasingly aware of the need for strong broadband infrastructure, much work remains going forward to develop policy and coordinate the investments necessary to ensure adequate broadband access across the spectrum of speed.

Access to Capital

Manufacturers in all stages of business development need access to capital to expand and grow. Early stage firms often require the support of venture capital and other investors to keep the doors open, yet established firms also need access to capital to implement new machinery, expand operations, or refinance or restructure debt. Financing is doubly important for innovation by funding research development projects or new advanced machinery. Since much of manufacturers' liquidity is tied up in inventory, they must often turn to outside financing when looking to expand operations.[232]

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[228] National Telecommunications and Information Administration and the Federal Communications Commission. *National Broadband Map.* US Department of Commerce.

[229] Broadband Illinois, *Leveraging the Power of the Internet in Illinois.*

[230] State of Illinois. *Illinois Gigabit Communities Challenge*.

[231] *Illinois Innovation Index.* May 2012 edition.

[232] Manufacturing Extension Partnership, "Connecting Small Manufacturers with the Capital Needed to Grow, Compete, and Succeed: Small Manufacturers Capital Access Inventory and Needs Assessment Report," November 2011.

Capital Intensity Indicator

Some manufacturing industries like leather or textiles are relatively capital-light while others including petroleum refineries or heavy equipment tend to have much larger capital expenditures. CMAP developed a capital intensity quotient to compare the capital outlay of Illinois manufacturing industries for machinery and facilities.[233] Illinois industries with a capital intensity quotient above one invest more capital in machinery and facilities compared the national average, while a measure below one indicates industries in the state spending less capital relative to the size of the workforce. While it is only one data point, the capital intensity indicator hints at what industries are making the capital investments today in order to compete in advanced manufacturing tomorrow. Those industries with a capital intensity above one may indicate growth opportunities here in Illinois as firms in these industries invest more in state of the art machinery, expanded facilities, data processing equipment and other improvements compared to those same industries in other states or regions. Conversely, industries with lower capital intensities, like computers/electronics, may not be investing for the next generation at a rate concurrent with competitor regions.[234]

Table 1. Capital Intensity Quotient

Illinois Industry	Capital Intensity*
Food/beverage	0.98
Apparel, furniture, other	1.05
Paper/printing	0.56
Primary	1.97
Chemicals/plastics	1.12
Fabricated metals	1.23
Machinery (including transportation & aerospace)	0.77
Computers/electronics	0.53
Health sciences	1.57

*Measures capital expenditure per worker compared to the national average.

Source: CMAP analysis of U.S. Census Annual Survey of Manufacturers data for year 2010.

Capital Opportunities

Without access to capital, firms cannot invest in next generation machinery, facilities, or equipment. With a finance and commercial banking sector with historic links to manufacturing, metropolitan Chicago has a capital infrastructure base that supports manufacturers looking to expand. Though the region's capital support networks may be less developed compared to regions like Silicon Valley in software and IT, the Chicago region appears to be specialized when it comes to financing manufacturing expansion.[235] According to Crain's Chicago Business, metropolitan Chicago has a network of venture capital and private equity firms specialized in manufacturing.[236] As the executive director of the Chicago-based Illinois Venture Capital

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[233] Sufficient data not available at the regional level so this measure uses data for the state of Illinois. The measure compares industry capital expenditure in machinery and facilities per worker in Illinois to the national average. Based on U.S. Census Annual Survey of Manufacturers data for year 2010.

[234] The state's lower measure in machinery derives from less spending in transportation and aerospace—two industries that nationally have large capital expenditures—while in industries like commercial or agricultural machinery the state has a capital quotient above one.

[235] Crain's Manufacturers Breakfast, November 15, 2012.

[236] H. Lee Murphy, "Investors still see gold in Rust Belt," Crain's Chicago Business, October 1, 2012.

Association explains, "Investors put money in what they know. Investors here in the middle of the country have in many cases come from the manufacturing sector. They're comfortable in a manufacturing environment."[237]

Finance Sector Maintains Close Ties to Manufacturing

A key strength of the region's capital infrastructure is its familiarity and close association with manufacturing. One regional example out of many is the private equity investment firm Industrial Opportunity Partners (IOP), LCC based in Evanston. Managing over $460 million in committed capital, the firm focuses on pursuing growth opportunities in mid-market manufacturing. Past experience in industries from agricultural and construction equipment to health care and food products touch on the strengths of the regional manufacturing cluster.

Source: IOP website.

Capital Challenges

Regional capital institutions' familiarity in financing manufacturing serves as an opportunity for cluster firms looking to expand, though a challenge remains in providing adequate financing options for smaller and startup firms. Currently venture capital and other investors in the region rarely invest in manufacturing at the seed or startup stage, instead focusing on ramping up production in more established firms.[238] The seed and startup stages however are the very stages when capital may be most needed because firms have fewer assets as collateral for loans. The Manufacturing Extension Partnership identified a funding need at levels between $150,000 and $500,000 in the current manufacturing financing system.[239] This funding level corresponds to the startup stage, as firms need initial investments to keep the doors open while developing their novel idea into a concrete commercial product. Thus less capital flowing to innovative firms at these early make-or-break stages of business development can stifle the growth of small firms. Providing more opportunities for seed and startup funding can help accelerate growth in the manufacturing cluster.

Clean Energy Trust Provides Early-Stage Support and Financing

The Clean Energy Trust provides business development support to clean energy startups in Illinois. In addition to commercialization strategies, promising technologies are eligible for financing through grants, loans, or equity. This earlystage financing helps overcome the funding gap for clean-tech firms. As the majority of clean-tech products will come from manufacturing, this resource could be used to support the manufacturing cluster.

Source: Clean Energy Trust website.

Energy Infrastructure

Manufacturing still consumes more energy in Illinois and the nation compared to any other end use. Manufacturing energy consumption varies across the country based on a number of factors including the mix of industries, firms' age of equipment, adoption of energy efficient technologies, and regional energy prices. Though energy cost is just one among many for

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[237] Maura O'Hara, quoted in Murphy, 2012.

[238] Murphy 2012; Manufacturing Extension Partnership 2011, p.57.

[239] Manufacturing Extension Partnership, 2011.

manufacturers, ample energy infrastructure is a way for regional clusters to gain an advantage in an ultra-competitive environment. At a recent manufacturing symposium, the CEO of a local manufacturing firm noted that energy was a "game changer." Those increasing efficiency and expanding input options would have an advantage over competitors.[240]

Energy Challenges

Compared to other states, Illinois has a slightly higher cost of key energy sources delivered to industry[241], which may be a challenge influencing future growth in the cluster. Of the three largest energy sources for manufacturing -- electricity, natural gas, and coal -- electricity in Illinois was about two percent more expensive than the national average for manufacturing firms, and ten percent higher compared to the other states in the Midwest in 2010. While a few percentage points may not seem prohibitive, they do add up when firms look at total cost of production. In natural gas, which manufacturers use more than any other end user, Illinois' rate of delivered energy to industry was about one-third higher than the national average in 2010. This may put Illinois at a disadvantage, though, since 2010, natural gas prices have fallen dramatically both in the state and the nation. In contrast to electricity and natural gas, the cost of coal in the state is lower than the national average by about 16 percent. These rates of energy sources suggest "that Illinois industry faces a mixed picture among different fuels."[242]

The cost of energy inputs appear to be increasing quicker in Illinois compared to the national average, a further challenge for the manufacturing cluster. Between 2000 and 2010, the cost of energy for manufacturers increased across the nation by 21 percent. In Illinois the increase was 25 percent, while the value of shipments this same period rose by only 14 percent.[243] The difference between the cost of energy and the value of shipments means that Illinois firms now must contribute more revenue per value of production towards energy than they had before.

Finally, industrial firms in Illinois under-utilize combined heat and power (CHP) systems. Traditional power plants create both heat and energy while generating electricity but generally only capture electricity while the heat is released into the natural environment through such measures as cooling towers. In contrast, in a CHP system that thermal energy is captured and used as energy. Additionally, CHP cogeneration systems tend to occur on-site. Up to two-thirds of the energy produced in a utility can be lost in the distribution to end use,[244] so producing energy onsite through a cogeneration plant maximizes energy efficiency.

In 2010, Illinois' existing CHP capacity in manufacturing facilities was about one-third the level of Michigan and half that of Indiana despite having larger total output than both those states.

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[240] Martin Swarbrick, CEO of Bison Gear & Engineering, Keynote Address at Manufacturers' Symposium, Elgin Community College, October 25, 2012.

[241] This analysis only looks at energy costs for industry, not rates for residential or commercial use.

[242] Bradbury and Aden, "Midwest Manufacturing Snapshot: Illinois," World Resources Institute, 2012, p.3.

[243] Ibid

[244] U.S. EPA, "Energy Trends in Selected Manufacturing Sectors," March 2007.

Illinois' total CHP capacity (including manufacturing facilities and that at hospitals, universities, and other uses) was three percent of total electricity production, far below the national average of eight percent. Compared to European countries this efficiency gap is even more striking: over half of all electricity generated in Denmark for example comes from cogeneration.[245]

Energy Opportunities

CHP can only be feasibly implemented at mega-facilities such as hospitals, universities, or large manufacturing plants that can both afford the cost of their own power generation but also have the demand to consume what is produced. In a 2012 study, the World Resources Institute combined data from a variety of sources to predict CHP potential in Illinois. The study found that existing industrial CHP potential (in other words, the number of existing manufacturing facilities that could implement CHP) in Illinois was the largest in the Midwest, totaling four times the currently installed capacity.[246] The main barrier remains cost, as firms in essence must built a mini-power plant on site. CHP would be an even more attractive option if firms could sell excess energy from their cogeneration back to the grid, which is difficult to do under the existing utility regulatory system.[247]

Increasing energy efficiency through CHP is one opportunity for the manufacturing cluster, and the state just received a grant from the National Governors Association to improve energy efficiency in manufacturing.[248] On the policy side, Illinois passed SB 1592 in 2007 to reduce peak demand at utilities and a federal executive order of August 2012 will accelerate investment in industrial energy efficiency.[249]

Finally, manufacturing energy consumption in the state is concentrated in only a few industries: primary metals, petroleum and coal products manufacturing, chemicals, and food manufacturing consume 70 percent of all the energy used by manufacturers in the state, but contribute just about a quarter of total manufacturing employment. [250] So while energy efficiency efforts will continue to be vital in these industries, other components of the manufacturing cluster—such as health sciences or advanced machinery—may be less reliant on the cost of energy inputs.

[245] James Bradbury and Nate Aden, "Midwest Manufacturing Snapshot: Energy Use and Efficiency Policies," World Resources Institute, 2012.

[246] Ibid

[247] Dan Ferber, "How capturing wasted energy can revive the Midwest," Recycled Energy Newsroom, September 7, 2012.

[248] Illinois Government News Network, "National Governors Association Selects Illinois For Industrial Energy Efficiency Grant," September 13, 2012.

[249] The White House, "Executive Order—Accelerating Investment in Industrial Energy Efficiency," Office of the Press Secretary, August 30, 2012.

[250] Bradbury and Aden, 2012.

Regional Firms Take Advantage of CHP Systems

Steel manufacturer ArcelorMittal saves $100 million annually from a CHP system at their East Chicago plant. The CHP system uses the heat generated from North America's largest blast furnace to generate 400 megawatts of thermal energy and 220 megawatts of electricity a year. To put that into perspective, this single CHP system produces more energy than all the existing wind turbines in both Illinois and Indiana combined.

In another regional example, Hoffer Plastics installed a CHP system at their Elgin facility in 1991. The Hoffer experience shows how CHP systems not only save money, but give firms more security. With the CHP system in place, the firm no longer has to worry about downtime due to power loss, and this security helps reassure prospective clients that orders will always be met on-time. Additionally, the firm has found the CHP system has given them more flexibility—some days it is still cheaper to run off the existing grid, but when prices fluctuate, the firm can run off its own generators.

Source: CMAP interview with Hoffer Plastics, and ArcelorMittal company website.

Next Steps: Enhance Competitive Advantage in Infrastructure

Make strategic investments in the region's transportation infrastructure, implement congestion pricing and innovative financing, and improve freight governance to preserve the region's locational advantage.

Of all types of infrastructure, transportation remains perhaps the most important for manufacturers. Past investments in the transportation system have given the Chicago region a competitive edge in the global economy, facilitating both regional supply chain moves and access to distant export markets. Metropolitan Chicago is the only domestic region served by six of the seven major railroads, boasts seven interstate highways in the region, and has the nation's second busiest airport in terms of international air cargo. Exports in particular benefit from this transportation access -- close to two-thirds of all of the region's exports come from manufactured goods moving through the regional transportation system.

Congestion threatens to undermine the transportation advantages currently enjoyed by manufacturers in the Chicago region. Like other parts of the country, the region is finding it more difficult to finance infrastructure improvements, as the methods and sources for financing transportation infrastructure are not keeping pace with the demand for maintenance, modernization, and expansion. To preserve its status as the nation's transportation and freight hub, the region can prioritize investment towards those projects best addressing regional mobility, such as the Elgin-O'Hare Western Access that would improve throughput and reliability for a major manufacturing corridor. Innovative financing through such measures as congestion pricing would provide regional revenue stream and also give commuters more choice. Finally, improved freight governance can guide investments, improve coordination, and reduce redundancies in the system.

Encourage infill growth in areas served by existing transportation assets to maximize existing land availability.

Future expansion in the manufacturing cluster is predicated on the availability of suitable land stock with access to transportation infrastructure and near a manufacturing savvy workforce. Current efforts like the City of Chicago's Planned Manufacturing District help ensure land for future manufacturing use and a real opportunity exists to orient manufacturing towards infill development. While many types of manufacturing -- such as smelting or refining -- will still need to be separated and concentrated in manufacturing districts, new types of manufacturing may be better integrated within broader uses and can be sited in existing communities. Finally, CMAP's LTA program can help individual municipalities match local land use to regional developments.

Augment early-stage financing opportunities for the most innovative manufacturers.

The region's existing capital infrastructure maintains a close connection to manufacturing, setting the region apart from other finance centers which may focus primarily on financing services, IT, or other non-manufacturing sectors. While the region's historic association between manufacturing and finance is a key strength of the cluster, more can be done to support access to capital for early stage startups. Increasing funding opportunities through venture capital and other measures can help foster growth in small manufacturing firms. The Clean Energy Trust -- which draws on the region's universities and research institutions, banks and investors, foundations and trade groups, and private firms to provide early stage business development services for clean-tech companies -- can serve as a model. The most promising technologies can access financing through grants, loans, and equity, helping address early stage funding gaps.

Phase out Cook County property tax assessment classification on industrial/commercial properties to address this regional discontinuity in taxation.

Cook County's current property tax assessment classification puts a disproportionate burden on manufacturers in the City of Chicago and nearby suburbs compared to the collar counties. This discontinuity creates an imbalance in regional industrial land development, impeding implementation of the GO TO 2040 recommendation for infill redevelopment to strengthen existing communities. Phasing out this assessment can help create more even development and land use across the region.

Incentivize CHP systems to increase energy efficiency.

One way for the regional manufacturing cluster to save money on energy inputs is to increase adoption of CHP systems. More efficient energy use can give firms a competitive edge, especially in energy-intensive industries such as metals, chemicals, or food. While CHP systems are only feasible on large-scale sites, metropolitan Chicago and Illinois have plenty of latent potential, up to four times currently installed capacity, likely more than any other region in the Midwest.

Through policy and collaboration with utilities the public sector can help incentivize CHP adoption. Over time CHP systems pay for themselves but the initial capital investment is too much for many firms to handle. One model to incentivize CHP adoption is for the utility to assist with upfront investment, with part of the energy savings each month dedicated to pay off the initial funding. The public sector can also work with the utility to make it simple for firms to sell excess energy from cogeneration back to the grid, which is difficult to do under the existing utility regulatory system. Many firms, especially large-scale plants, may be able to use CHP to produce more energy than they actually use; knowing they could sell the excess back to the grid would be a further incentive to adoption this energy investment.

Conclusion

Manufacturing is and must continue to be a thriving component of the region's broad economy. While global offshoring may have characterized the last ten years of American manufacturing, the next ten could instead be defined by reinvestments in domestic clusters. Supply-chain vulnerabilities, exacting quality requirements, accelerated shifts in consumer demand, and rising international labor costs have eroded prior cost advantages of producing overseas, leading some production to return to the U.S. Nurturing the type of advanced manufacturing that leverages metropolitan Chicago's competitive advantages will best position the region to realize future cluster growth. Achieving a balance of private and public solutions to innovation, infrastructure, and workforce challenges will be the key to maintaining metropolitan Chicago's status as a leader in modern manufacturing and global commerce in the 21st Century.

List of Acronyms

ACT	American College Testing
AIDT	Alabama Industrial Development Training
APA	Austin Polytechnic Academy
ATUM	Association of University Technology Managers
BLS	Bureau of Labor Statistics
CAD	Computer-Aided Design
CHP	Combined Heat and Power
CMAP	Chicago Metropolitan Agency for Planning
CNC	Computer Numerically-Controlled
CREATE	Chicago Region Environmental and Transportation Efficiency Program
DOC	U.S. Department of Commerce
ESMI	Economic Modeling Specialists Inc.
ETIP	Employer Training Investment Program
GBPS	Gigabytes Per Second
GDP	Gross Domestic Product
IMA	Illinois Manufacturers' Association
IMEC	Illinois Manufacturing Extension Center
IT	Information Technology
LQ	Location Quotient
LTA	Local Technical Assistance
OEM	Original Equipment Manufacturer
MBPS	Megabytes Per Second
MCIP	Manufacturing Careers Internship Program
MIT	Massachusetts Institute of Technology
MSSC	Manufacturing Skills Standards Council
NAFTA	North American Free Trade Agreement
NAICS	North American Industry Classification System
NAM	National Association of Manufacturers
NCRC	National Career Readiness Certificate
NIMS	National Institute of Metalworking Skills
NMI	National Manufacturers' Institute
NNMI	National Network for Manufacturing
NSF	National Science Foundation
R&D	Research and Development
SBIR	Small Business Innovation Research
SEZ	Special Economic Zone
SME	Small and Medium-Size Enterprises
SME	Society of Manufacturing Engineers
STEM	Science, Engineering, Technology, and Math
STTR	Small Business Technology Transfer
UIC	University of Illinois at Chicago
WTO	World Trade Organization

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The Chicago Metropolitan Agency for Planning (CMAP) is the region's official comprehensive planning organization. Its GO TO 2040 planning campaign is helping the region's seven counties and 284 communities to implement strategies that address transportation, housing, economic development, open space, the environment, and other quality of life issues.

See **www.cmap.illinois.gov** for more information.

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